LAKESHORE CAPACITY STUDY

MICROBIOLOGY

MARCH 1983

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Ministry of the Environment

For:
Ministry of
Municipal Affairs and Housing

Ontario

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LAKESHORE CAPACITY STUDY

MICROBIOLOGY COMPONENT

Muskoka-Haliburton Area

0 5 10 15 20 25 30 35

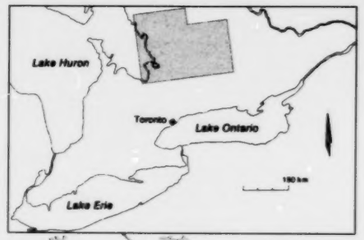
Scale in kilometre

- Water and sediment fecal indicators and some pathogens
- Identification of some heterotrophic bacteria
- Chemical analysis of water and sediment
- Otitis externa
- Questionaire

1975 ■ 1978 ■
1976 ■ 1979 ■
1977 ■

Note: Symbol sizes for cartographic purposes only

Cartography by Ministry of Municipal Affairs and Housing, 1982



LAKESHORE CAPACITY STUDY

Muskoka-Haliburton Area

0 5 10 15 20 25 30 35

Scale in kilometres

COMPONENTS:

- Wildlife
- Trophic Status
- All
- Microbiology
- Fisheries
- Land Use

The regional survey by the Land Use Component of cottages on portions of lakes is not included

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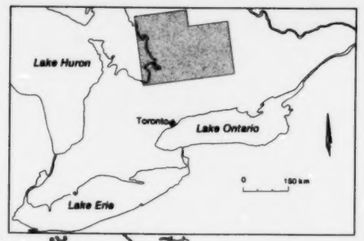

Eagle Lake
Bernard Lake
Pickerel Lake
Island Lake
Grass Lake
Jacks Lake
Loon Lake
Sand Lake
Three Mile Lake
Groom Lake
Peters Lake
Clam Lake
Doe Lake
Emsdale
Clear Lake
Foote Lake
Dotty Lake
Oxbow Lake
Perch Lake
Walker Lake
Bella Lake
Oudaze Lake
Rebecca Lake
Little Clear Lake
Buck Lake
Jerry Lake
Solitaire Lake
Harp Lake
Troutspawn Lake
Lower Fletcher Lake
Bear Lake
Seventeen Mile Lake
McFadden Lake
Clinto Lake
Lake Vernon
Peninsula Lake
Hurds Fairy Lake
Tock Lake
Kawagama Lake
Johnson Lake
Macdonald Lake
North Lake
Percy Lake
Haliburton Lake
Redstone Lake
Kennisis Lake
Eagle Lake
Moose Lake
Mary Lake
Beattie Lake
Menominee Lake
Lake of Bays
Mink Lake
Paint Lake
Shoe Lake
Mouse Lake
Plastic Lake
Big Hawk Lake
Little Hawk Lake
Maple Lake
Clearwater Lake
Grandview Lake
Chub Lake
Martin Lake
Blue Chalk Lake
Black Lake
Red Chalk Lake
Kabakwa Lake
Halls Lake
Fawn Lake
Big Stephen Lake
Moot Lake
Echo Lake
Ril Lake
Dickie Lake
Wildcat Lake
Bonnie Lake
Sage Lake
Gullfeather Lake
Pine Lake
Croason Lake
Gilleach Lake
Healey Lake
McKay Lake
Leech Lake
Wood Lake
Cinder Lake
Brady Lake
Kushog Lake
Boshkung Lake
Twelve Mile Lake
Hurricane Lake
Green Lake
Glen Lake
Bessaunt Lake
Two Islands Lake
Mishwabi Lake
Long Lake
Head Lake
Mountain Lake
Kashagawigamog Lake
Glamour Lake
Billings Lake
Silent Lake
Bancroft
Eason Lake
Stewart Lake
Leonard Lake
Bigwind Lake
Bird Lake
Little Bob Lake
Gull Lake
Sludge Lake
Davis Lake
Head Lake
Four Mile Lake
Dairymple Lake
Lake Couchiching
Orillia
Mississagua Lake
Lower Buckhorn Lake
Lovesick Lake
Lake St. Peter
Skeleton Lake
Kahshe Lake
Three Mile Lake
Graverhurst
Muskoka Bay
Bracebridge
Parry Sound

THE DISTRICT OF PARRY SOUND
THE DISTRICT MUNICIPALITY OF MUSKOKA
THE DISTRICT OF NIPISSING
PROVISIONAL COUNTY OF HALIBURTON
THE COUNTY OF HASTINGS
THE COUNTY OF VICTORIA
THE COUNTY OF SIMCOE
THE PROVISIONAL COUNTY OF HALIBURTON
THE COUNTY OF PETERBOROUGH

Black River
Gull River
Ironside River
Severn River

FOREWORD

The Lakeshore Capacity Study was undertaken to provide a planning tool to assist in managing the development of Ontario's inland lakes. Basic to this task was the need to develop an improved understanding of the relationships between cottage development on the lakeshore and selected aspects of the environment. To accomplish these objectives the Ministry of Municipal Affairs and Housing, responsible for the Study, worked with the ministries of the Environment and Natural Resources.

The Muskoka-Haliburton area of central Ontario was chosen as the study area. This area lies within one physiographic region, part of the Precambrian shield, with similar soils and plant communities. The homogeneity reduced the need to account for major natural variations among the lakes and watersheds. Further, the extent of existing development on the lakes varied; permitting an examination of situations extending from no development to "full" development.

The Study involved measurement of the source of the environmental impact, the cottages and their use, and how development affects the indicators of impact: nutrient enrichment; public health; fish, angling and littoral zone; and wildlife and habitat modification. The research findings were linked in a simulation model. The model can predict trends for the various impacts on the watershed.

The Microbiology report examines the relationship of beach use to risk of ear infection. The bacterium *Pseudomonas aeruginosa* causes the ear infection and is transmitted by the swimmers through water, from ear to ear. The major achievement has been the development of quantitative cause-and-effect relationships between swimming and *P. aeruginosa* levels.

The objective of this phase of the Lakeshore Capacity Study, to develop a practical planning tool for lake-watershed management, has been achieved. The next step is further testing prior to implementation.

M.H. Sinclair
Chairman
Lakeshore Capacity Study

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SUMMARY

The purpose of the Microbiology Component of the Lakeshore Capacity Study was to examine and quantify the relationships among lakeshore development and the recreational activities, the microbiological quality of the lake waters and the incidence of disease among the human users of the water. Between 1976 and 1979, studies were carried out in the Muskoka-Haliburton area of Ontario to determine the water quality of a number of lakes and a few public access beaches and to assess the incidence of human illness. The work centered around the bacterium, *Pseudomonas aeruginosa* and its relationship to an external ear infection called *otitis externa*. *P. aeruginosa* was found to be absent from or in very low levels in the surface waters. When it was found, it was usually found in association with human activities, such as swimming and the levels found were highly variable over both time and space. The levels of *P. aeruginosa* present in surface waters were related to the water temperature and to the amount of human use, e.g. *P. areuginosa* levels increased as the number of swimmers in a swimming area increased. The availability of nutrients for growth may have affected the levels of *P. aeruginosa* present in surface waters.

During a summer, eight to twelve swimmers out of a population of 100 contracted an ear infection. The incidence of ear infection was seasonally variable with most infections occurring in July and August. Swimmers in the 5 to 24 year age group, those that swam very frequently and those with a previous history of ear infections, were the most likely to contract an ear infection. The incidence of ear infections was related to the level of *Pseudomonas* present in the water of the swimming area. Noticeable effects on the incidence of ear infection were seen as the levels of *P. aeruginosa* in the water showed a median level of 0 per 100 mL, i.e. no *Pseudomonas* was detected, and a 75 percentile level in the range 10 to 100 per 100 mL.

The model developed and the statements made as a result of this study suggest a water quality criterion and design criteria which should be used to reduce the risk of ear infection. Design criteria for water and sewage processes in a development were also recognized.

1. INTRODUCTION AND BACKGROUND

Throughout the four years of field operations the Microbiology Component undertook the task to state quantitatively the public health significance of waterborne bacteria whose populations are most apparently influenced by human usage of the recreational lake environment. The use of water for recreational or drinking purposes was to be related to the risk of disease for the human user associated with lakeshore developments.

1.1 BACTERIAL WATER QUALITY

Because of the numerous uses of water by humans, it is not surprising that water has been directly and indirectly involved with numerous outbreaks and single cases of human disease (Craun 1978a,1979b). Disease occurs when pathogenic or disease-causing microorganisms are ingested, gain entry into a cut or wound, or invade any of the mucous membranes of the human body and water provides a means of transport for the microorganism. While the importance of other microorganisms (fungi, algae, protozoans and viruses) to public health, is acknowledged, this study concentrated upon examining the bacteriological quality of water of recreational lakes.

The quality of surface waters used for drinking and recreational purposes is degraded by the introduction of pathogenic bacteria which are released from the body via the feces. Groups of bacteria, called indicators (total coliforms, fecal coliforms and fecal streptococci) occur at higher concentrations in the intestinal tract, feces and sewage than the pathogenic bacteria. In water above a specified concentration, indictators suggest, firstly, that recent contamination with fecal materials may have occurred, and secondly, that the presence of disease-causing microorganisms is likely to produce an unacceptable risk of disease. Therefore, the greater the concentration of fecal indicators the greater is the likelihood of the presence of pathogenic microorganisms and greater is the risk to health of the users of the contaminated waters. The current guidelines for the assessment of bacteriological water quality (Ministry of the Environment 1978a) have been formulated using this relationship.

However, the aquatic environment is usually hostile to the indicator and pathogenic bacteria. The stresses which fecal bacteria encounter in water (Daubner 1975) will eventually decrease their numbers. In practical terms, therefore, the levels of indictor bacteria and pathogens detected in water will usually decrease with time and distance from the pollution source. This means that any public health significance is both site and time specific. For example, a pollution discharge near one end of a long beach may cause a problem at that end of the beach but not at the other end. If the discharge is stopped, the problem would probably disappear over time.

The expected relationship between indicator densities and pathogen densities also change with time and distance. Differential rates of survival in water allow some of the microorganisms found in fecal material to survive for longer periods than others (Geldreich and Kenner 1969) particularly when the water contains relatively high levels of organic nutrients.

Prolonged survival of indicator and of pathogenic microorganisms has frequently been reported in enriched waters and in aquatic sediments (McFeters and Stuart 1972; Goyal et al 1977; Smith et al 1978; LaBelle et al 1980), and in some waters fecal bacteria have been shown to be capable of regrowth (Gorden and Fliermans 1978). Thus, enriched waters and aquatic sediments are potential reservoirs of feces-derived microorganisms which might be resuspended by environmental factors such as wave action and by recreational activities such as swimming and motor-boating (Geldreich 1970; Gerba and MacLeod 1976; Goyal et al 1977). In areas subject to sporadic sewage discharge, this potential reservoir will appear as the presence of pathogenic mircoorganisms, not predicted by the densities of indicator bacteria (Cabelli 1978). In practical terms, sewage pollution could periodically exert a localized detrimental influence on the water quality of bathing beaches and shoreline areas long after the water quality effects of the original pollution have disappeared from surface water. For these reasons surface waters should never be used for drinking purposes without the benefit of adequate disinfection (Ministry of Environment 1978b).

The microbial populations of the lakes and other surface waters are comprised of numerous genera and species. With the exception of a few recently reported species (*Aeromonas hydrophila, P. aeruginosa, Yersinia enterocolitica)* most bacteria in water are considered to be harmless, normal inhabitants of the aquatic environment. In the natural setting these bacteria are of little or no public health significance although they may be of vital importance in the food webs (nutrient cycling, decomposition) and self-purification of lakes (Wetzel 1975). Nutrient-enrichment or thermal alteration of the environment as a result of human activity or natural calamity, creates an imbalance in the bacterial populations. Increased bacterial densities may result in conditions such as oxygen depletion, fish disease epidemics, and growth of potentially pathogenic bacteria such as *Aeromonas hydrophila* (Cabelli 1973, 1978; Cook et al 1978). While considerable evidence for the involvement of waterborne bacteria in human disease exists (Craun 1978a, b; Pipes 1978), there is currently a lack of conclusive evidence concerning the significance to human health of pathogens which grow in the aquatic environment in response to pollution. Some evidence exists for the involvement of human pathogens in the disease of fish exposed to polluted waters (Hazen 1979; Robohm et al 1979). The

growth of some of these bacteria in response to nutrient or thermal pollution may also be of human health significance. In recreational lakes where pollution sources are usually quite diffuse, the bacterial response to nutrients might be very difficult to determine until the entire lake, rather than specific sites, is affected. Near major sources of pollution, however, these effects might be readily detected particularly in seasons of warm water temperatures and in sheltered bays.

1.2 PUBLIC HEALTH SIGNIFICANCE AND USE

Previous studies have provided little quantitative information about relationships between recreational activity and bacterial densities in water and virtually no information about the incidence of human illnesses. Several studies have concluded that gross recreational activities had little or no influence upon bacteriological water quality of lakes or watersheds (Rosebery 1964; Walter and Bottman 1967; Carswell et al 1969). These studies did indicate, however, that localized water quality degradation occurred on shoreline receiving intensive recreational activity during the summer season. The increased bacterial levels observed at sites such as bathing beaches had no long-term influence on water quality of either the most affected sites or on the lake or watershed as a whole. Other reports, however, concluded that recreational use of reservoirs or watersheds intended for supply of municipal waters caused deterioration of the water quality of both localized site and of the whole body of water (Karalekas and Lynch 1965; Kleemola 1971; Stuart et al 1971; Dietrich and Mulamottil 1974; Skinner et al 1974; Wagenet and Lawrence 1974; Baker and Magnuson 1976). A recent study suggested both a degradation of water quality and the existence of a potential health hazard in downstream reaches of a watershed during periods of intensive human use of upstream camping areas (Varness et al 1978).

These conflicting conclusions concerning the influence of recreational activities may be attributable to the failure of most studies to take into account the effect of countermeasures (e.g. septic system, disinfection), to quantitatively determine the effect of the populations of animals (Walter and Bottman 1967; Lee et al 1970), the degree of dispersion of recreational activities (Varness et al 1978), and the degree of human use (Lee et al 1970) in each watershed examined. For instance, although Lee et al (1970) detected pathogenic bacteria in the downstream reaches of each watershed, they were unable to show a quantitative influence of human usage upon bacterial indicator populations in any of the watersheds. The study employed a measure of human use (man days per square mile) and wildlife (game animals per square mile) in an attempt to determine the influence of human use levels on the bacteriological quantity of 3 watersheds, only one of which was protected from recreational use. They concluded that since the game animals use was estimated to be much higher than the human use in each watershed, the influence of the humans was not detectable with current methods due to the dominant influence of the animals. In these watersheds animals were considered to be the major contributors of pollution which resulted in the fecal coliform densities observed. They recommended that watersheds with relatively higher levels of human use be examined to determine what level of human use would influence indicator bacterial densities. Unfortunately this recommendation has not been incorporated in subsequent studies of relationships between land use and water quality. With the exception of a few site specific investigations (Cabelli et al 1976, 1979; Fraser 1977), little information exists concerning the incidence of disease among human users of recreational waters. Nevertheless three major aspects of lakeshore development and land use can be considered to be very important to the manifestation of disease among human users of recreational lakes. These are: 1) use of water for drinking; 2) use of sewage systems; and 3) use of water for recreation, particularly body-contact activities such as swimming.

1.3 DRINKING WATER AND ILLNESS

Users of lakeshore developments require water of good quality for drinking, food preparation, personal hygiene, and for other domestic purposes. In the past decade numerous outbreaks of human illnesses, particularly gastroenteritis, have been attributable to the drinking of untreated ground and surface waters amd waters from supplies with deficient treatment systems (Craun 1978a, b; 1979b; Pipes 1978). Infections caused by bacteria (cholera dysentery, typhoid, tuberculosis), viruses (hepatitis, polio) and parasites (trinchinosis, amoebiasis, lambliasis) are frequently waterborne. But the majority of outbreaks and cases often involved drinking waters for which no causal organism could be conclusively demonstrated (McCabe 1977). Many of these latter outbreaks involving gastroenteritis, however, were probably caused by three recently recognized pathogens, *Yersinia enteroclitica*, enteropathogenic *Escherichia coli* and *Giardia lamblia* (Craun 1979a). Each of these are frequently encountered in surface waters. Because of the possible presence of pathogenic microorganisms in surface waters and because of the frequent fecal contamination of ground waters by leachates from septic tank systems (Sandhu et al 1979), water supplies intended for drinking purposes must be treated in some manner in order to protect the health of the consumers. This is especially significant to cottagers and recreationists whose water supplies are most often lakewater or whose wells are situated on lakeshore lots close to septic tanks or to potentially contaminated surface waters. The risk of waterborne illness can be markedly reduced by simple but important sanitary considerations: the boiling or other thorough disinfection of surface waters before consumption; and the proper installation and maintenence of wells and sewage systems (Ministry of Environment 1978b).

1.4 SEWAGE TREATMENT AND ILLNESS

Production of fecal material is an inherent consequence of the human or animal presence in the recreational lake environment. Sewage pollution resulting from improper storage, treatment or disposal of fecal waste materials, or from excessive discharges of treated sewage, can have serious detrimental influences upon the ecology and water quality of lakes and rivers (Hynes 1960; Piecynska 1975; Bell et al 1976; Jumppanen 1976; Gibbs 1977; Ministry of Environment 1978b) and on ground water quality (Craun 1979b; Sandhu et al 1979; Goyal et al 1980).

Considerable advances have been made in controlling the undesirable influences of sewage pollution related to the eutrophication of lakes (Dillon and Rigler 1975; Jorgensen 1976; Burton and King 1979) but from the public health stand-

point sewage pollution continues to be involved in many outbreaks and cases of waterborne human illnesses (Craun 1979b). Sewage pollution has been associated with bacterial and viral infections contracted by bathers using recreational waters (Denis et al 1974; Rosenberg et al 1976) but is more frequently associated as the cause of outbreaks involving contaminated drinking waters. For instance, from 1971 to 1977 there were 192 outbreaks and 36,757 cases of illness related to the consumption of contaminated drinking waters in the United States (Craun 1979c). Overflow from septic tanks and cesspools accounted for 42% of those waterborne outbreaks. Septic tank systems, as employed by most cottagers usually must handle a combined sewage and domestic wastewater load of about 126 litres per user per day (Brandes 1978). Because of the high nutrient and bacterial content of this wastewater, the septic systems must be properly designed, installed and operated to prevent contamination of surrounding ground and surface waters. Although septic systems may contribute to water quality degradation (Gibbs 1977), their impact on bacteriological quality of lake waters seems to be limited to areas nearest defective or substandard systems (Hendry and Toth 1980). Major impacts on water quality associated with sewage pollution therefore may be qualitatively and quantitatively observed at point sources, particularly those near outfalls of larger treatment systems which serve developments with higher human use levels. Regardless of source, however, sewage pollution is the major contributor of infectious disease microorganisms to drinking and recreational waters (Cabelli 1978; Craun 1979b).

1.5 RECREATIONAL USE AND ILLNESS

Reports of outbreaks of human illness associated with swimming have been relatively uncommon although several serious outbreaks of bacterial and viral infections due to swimming have been reported (Rosenberg et al 1976; Davis et al 1974; Pipes 1978). A correlation between the incidence of gastronintestinal illness among swimmers and fecal coliform (*Escherichia coli*) densities has been demonstrated at marine bathing beaches (Cabelli et al 1976, 1979). The human diseases associated with swimming have also been from wound infections by *Aeromonas hydrophila* (Rosenthal et al 1974; Hanson et al 1977) and infections of the eyes, ears, nose, skin and throat by a variety of bacteria and viruses. Of these, the ear infection, *otitis externa* or "swimmer's ear," caused by the bacterium *P. aeruginosa* (Jones 1965; Cassisi et al 1977), accounts for the majority of reported swimming-related illnesses. The bacterial indicator systems usually employed to determine water quality and health significance of drinking waters, often are unreliable in predicting the presence of pathogentic microbes in recreational waters and the health risks associated with swimming (Foster et al 1971; Dudley et al 1976; Geldreich 1976; Cabelli 1978; Pipes 1978; Reasoner 1978; Cabelli et al 1975, 1976, 1979). Several reports (Cabelli 1978; Pipes 1978) have recommended the use of *P. aeruginosa, A. hydrophila* and other quantifiable microbes of health significance as new indicator systems for assessing recreational water quality. *P. aeruginosa* has been included as an indicator of a potential health hazard in bathing waters in Ontario (Ministry of Environment 1978a).

The infectious microoganisms found in recreational waters can come from one of three sources, pollution by human or animal sewage, the washing of the skin of the bathers (Robinton and Mood 1966; Hanes and Fassa 1971) or the resident population of environmental microbes. The latter of these sources is generally not controllable but seems to play a minor role in the causation of human disease. For either of the other two sources, the contribution of the infectious agent to the recreational waters is dependent on factors such as the level of the illness in the contributing population, the number of carriers of the agent and the effective countermeasures taken (Cabelli 1978). As a result, if large human populations are present, the probablity of encountering ill or diseased individuals or carriers is very high and therefore, the occurrence of the infectious organism in the source is almost a certainty. However, with very small populations, such as the bathers at a single beach or the residents of a group of cottages, the probability of an ill individual or a carrier being present in the population is correspondingly very small. Under these circumstances, the occurrence of the infectious organism will be sporadic and the usual indicator systems may fail. This failure arises from a breakdown in the indicator-pathogen relationship on which the indicator system depends. Determination of the concentration of pathogen directly alleviates this problem but is generally more costly and is technically more difficult, if not impossible, depending on the infectious agent.

Sources of infectious agents which originate from sewage can be effectively removed by appropriate countermeasures such as adequate treatment and disinfection. However, the direct contribution of infectious agent by the bathers themselves through the washing of skin has largely been ignored and is poorly understood. Effective countermeasures for this latter source are generally not possible.

1.6 *PSEUDOMONAS AERUGINOSA — OTITIS EXTERNA*

This study was set up to examine the recreational water quality as it relates to the bacterium, *P. aeruginosa* and the ear infection, *otitis externa* . *P. aeruginosa* is a bacterium known to cause skin rashes (Kush and Hoadley 1980) and eye infections (Wilson and Ahearn 1977) and is the primary organism associated with the ear infection, *otitis externa* (Alcock 1977; Cassisi et al 1977). It appears to be "associated primarily with man" and "slightly in excess of 10% among healthy adults" in the United States are intestinal carries of *P. aeruginosa* (Hoadley 1977). It can therefore be routinely in human sewage and has been proposed as an indicator of sewage pollution (Cabelli 1977). As an infectious agent *P. aeruginosa* is described as an opportunistic pathogen. The organism may be present without apparent illness or disease but if the resistance of the host has been reduced by trauma, other diseases, medication or predisposition, a secondary infection by *Pseudomonas* can occur.

Although a direct correlation has not been established for ear infections due to waterborne *P. aeruginosa* , the reported incidence of *otitis externa* is higher among swimmers than non-swimmers (Hoadley and Knight 1975). Ear infections due to this bacterium may occur among swimmers even when low densities of *P. aeruginosa* are present in the bathing water (Seyfried and Fraser 1978).

1.7 *PSEUDOMONAS — OTITIS* MODEL

A model for the relationship of such factors as the chemical and physical environment, and human use and activity with *P. aeruginosa* and the illness, *otitis externa* is presented as a flow diagram in Figure 1. This model is supported by the general microbiology literature and by the general inclination of microbial ecology.

P. aeruginosa along with many other bacteria is a normal inhabitant of the human gastro-intestinal system (Hoadley 1977). These bacteria aid in the digestion of food by the human and are excreted in large numbers with the feces or waste products of human digestion (Boxes A and B). The bacteria including the *Pseudomonas* will, therefore be found in sewage and the normal treatment processes associated with sewage. Through this mechanism, *Pseudomonas* can be introduced to the environment, in particular, to the water. In addition, the washing of the human body which occurs during swimming activity will introduce *Pseudomonas* and other bacteria into the water (Hanes and Fossa 1971). These bacteria will come from the entire skin surface of the human but in particular the anal area.

Once in the water, the *Pseudomonas* and other bacteria whether they came from sewage or skin washings can be reintroduced into the human population through the use of the water for drinking, washing or food preparation purposes (Box D).

The survival and growth of *Pseudomonas* in the environment is dependent upon a number of factors including the water temperature, the chemical nutrients available and the interactions which occur between microorganisms (Box E). Hoadley (1977) suggests that in "unpolluted but organically enriched surface waters when water temperatures exceeded 30°C, growth might occur when the temperatures were high." At temperatures lower than 30°C, *Pseudomonas* is not growing but longer survival will occur. The definition of "organically enriched surface waters" has yet to be explored and what chemicals constitute organic enrichment for a particular bacterium are not known in detail. Hoadley (1977) does however add that *P. aeruginosa* "does not normally inhabit northern temperature surface waters unless recently affected by human activity or the activities of domestic animals."

The contribution of animals to the cycling of *P. aeruginosa* appears to be largely as a passive carrier rather than a reservoir (Hoadley and McCoy 1968). Therefore, their contribution will be minimal (Box F).

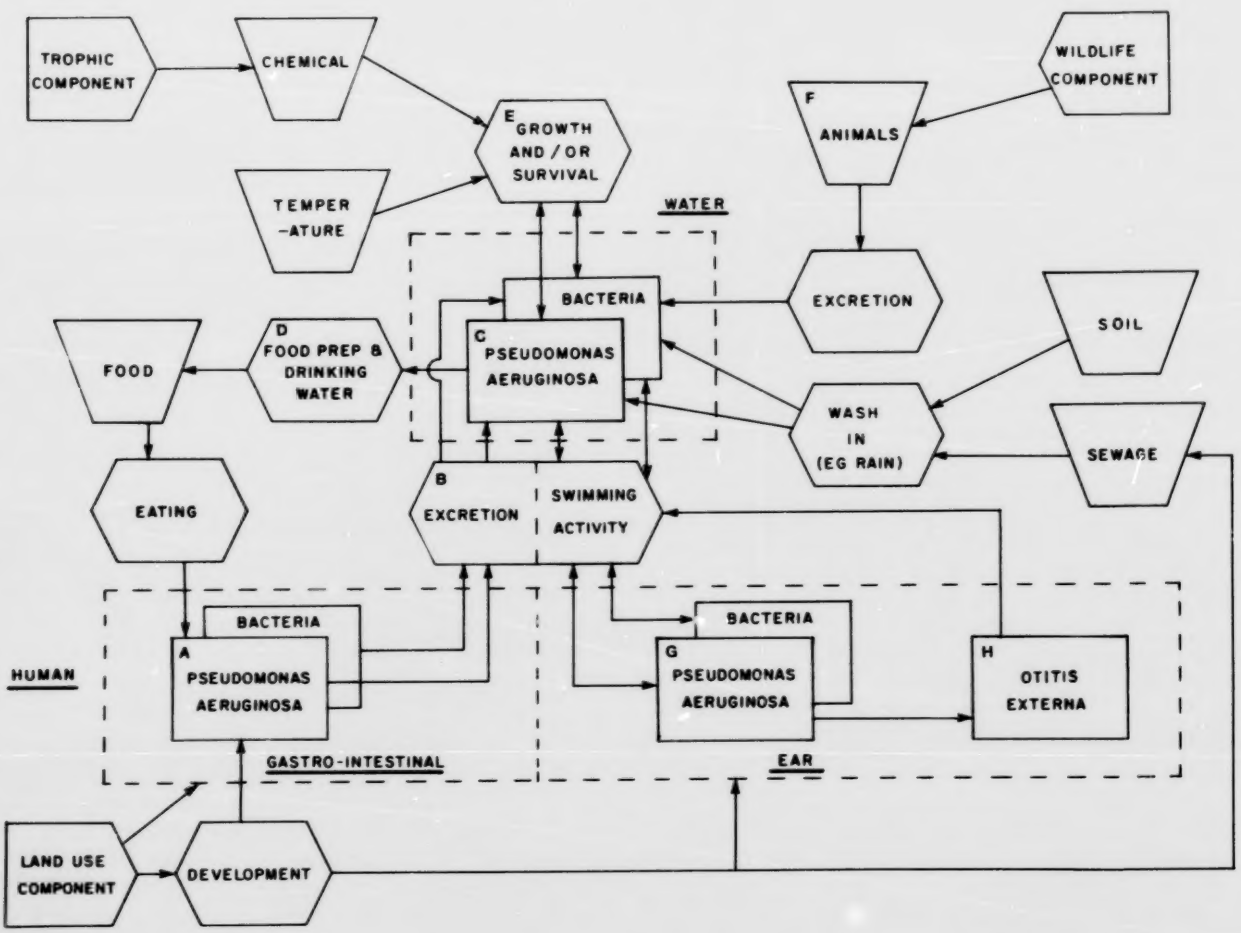

Figure 1: Flow diagram for *P. aeruginosa* and its relationship to swimming activity and the ear infection, *otitis externa*.

The portion of the model which this study examined most intensively was the linkages between *Pseudomonas* in the water, swimming activity, and *Pseudomonas* in the ear of a human user.

When a person goes swimming in the water which contains *P. aeruginosa* and the person submerges their head under the water, a small but definable portion of water enters the ear canal carrying the *Pseudomonas* with it (Box G.) This water with its bacterial content may drain out or be dried out without any further action or may moisten the ear canal contents and remain for some considerable time. The bacteria may also settle out or adhere to the inner surfaces, even though the water may be removed, leaving behind the bacteria. Once the *Pseudomonas* has gained access to the ear, an ear infection can occur (Box H). The process by which the infection occurs is poorly understood. However the people in the age group 5 to 15 years, the people who swim very frequently during any month and the people who have experienced a previous ear infection seem to be more likely to contract an ear infection. In either the case where *Pseudomonas* is in the ear with no apparent illness or the case where *Pseudomonas* has caused an ear infection, further swimming activity by that individual may reintroduce the *Pseudomonas* back into the water environment at the location of the swimming activity. Hoadley and Knight (1975) examined the ears of both healthy individuals and those with an ear infection. *P. aeruginosa* was found in 78% of the swabs from infected ears of swimmers and 33% of the swabs from infected ears of non-swimmers. The corresponding figures for a control population without ear infections were 11% and 14% respectively. They found a seasonal effect on the frequency of isolation of *Pseudomonas* from ears. Their telephone survey showed that 7.3% of the general swimmer population and 3.1% of the non-swimmers experienced earaches during the summer season. Seyfried and Fraser (1978) showed a higher isolation of *P. aeruginosa* and a higher incidence of otitis externa ear infection among the subjects using a swimming pool with a higher contamination with *Pseudomonas*. In both studies, the levels of *P. aeruginosa* in the water were low, 0 to 100 per 100 mL, and were very highly variable.

2. STUDY AREA

During the course of the Lakeshore Capacity Study, twenty-four lakes in the Muskoka-Haliburton area of Ontario were examined for bacterial and chemical water quality (Table 1). These lakes were examined in sufficient detail to permit comments to be made concerning possible relations between development effects and bacterial water quality. For this report, water quality will be discussed in generalities using specific examples and no lake will be discussed in detail.

Table 1. List of lakes in the study 1976-1979 and the total number of surface samples examined for the bacteria *P. aeruginosa* excluding beach samples.

Lake	Year	NUMBER OF SAMPLES BY SEASON		
		Spring (May-June)	Summer (July-Aug.)	Fall (Sept.-Nov.)
1. Pine	1979	28	56	–
2. St. Mary	1979	42	14	–
3. Seventeen Mile	1979	20	32	–
4. Buck	1979	18	27	–
5. Head	1979	42	84	–
6. Vernon	1979	42	125	–
7. Mary	1979	42	121	–
8. Twelve Mile	1979	14	42	–
9. Walker	1976	–	24	18
	1977	6	56	–
	1978	41	42	–
	1979	42	28	–
10. Muskoka Bay	1977	42	56	41
	1978	83	42	14
	1979	54	42	–
11. Gull	1978	122	126	126
	1979	55	98	–
12. Jerry	1976	–	18	18
	1977	6	56	–
	1978	41	42	28
	1979	2	14	–
13. Three Mile	1977	42	36	–
a) east half	1978	40	–	–
b) west half	1977	42	56	58
	1978	56	27	–
14. Hurricane	1977	5	42	–
	1978	28	56	–
15. Harp	1976	–	18	18
	1977	6	52	–
16. Fawn	1977	6	53	–
17. Chub	1976	–	18	17
	1977	6	–	–
18. Dickie	1976	–	18	18
	1977	6	–	–
19. Kahshe				
a) east half	1977	6	–	–
b) west half	1977	6	–	–
20. Stewart	1977	6	–	–
21. Red Chalk	1976	–	18	18
	1977	6	–	–
22. Blue Chalk	1976	–	18	18
	1977	6	–	–
23. Leonard	1977	6	–	–
24. Miskwabi	1977	6	–	–

Initially, the lakes studied by the Microbiology Component were chosen from among those also studied by the Trophic Status Component and had varying numbers of cottages or other forms of development along the shoreline. A few lakes (e.g. Jerry Lake) were undeveloped with respect to cottages and human usage. The cottages were organized as mainly single-tier cottage developments. The degree of dispersal of cottages along the shorelines varied. The undeveloped shorelines were mostly forested but some were used for agricultural rather than recreational purposes. Road access to the lakes and cottages was usually available. The cottages were serviced by septic tank sewage treatment systems. Lake water, with a varying amount of treatment, was the usual form of drinking water supply. A few lakes (e.g. Muskoka Bay and Gull Lake) were situated in urban areas with municipal sewage and water treatment plants. There were one or more marinas and commercial developments such as lodges or resorts.

In 1979, the lakes examined had at least one public access beach which was intensively used for recreation particularly during the summer months. The water quality of specific beaches (Table 2) was also examined. In general, these beaches were about 100 metres wide with a gently sloping sand bottom. The boundaries of the beach swimming areas were usually delineated by floating marker ropes and the area patrolled by lifeguards. Floating or permanent docks may have been in the vicinity, some serving as diving platforms. These beaches provided sites for organized swimming classes during the week but were also available to the general public at all times.

Table 2. List of beaches studied as part of the Lakeshore Capacity Microbiology Component.

Beach	Lake	Nearest Town	Year
No name	Gull	Gravenhurst	1977, 78, 79
Rotary	Head	Haliburton	1979
Lion's	Mary	Port Sydney	1979
No name	Pine	West Guilford	1979
Kinsmen	Vernon	Huntsville	1979
Public	Twelve Mile	Carnarvon	1979
Red Cross	Twelve Mile	Carnarvon	1979

At each beach there was an associated dry-beach sand area and a treed park and picnic area. The study beaches represent a large number of the public access beaches in the Muskoka-Haliburton area. This report will be examining beaches as a class of recreational use of the small lakes in the Muskoka-Haliburton area.

Figures 2, 3 and 4 are sketch maps of Muskoka Bay, Gull Lake and Head Lake, respectively, showing the locations at which water or sediment samples and some general

geographical information were obtained. Figures 5 and 6 are sketch maps of Gull Lake beach and Head Lake beach showing the sampling locations and the general relationship of the swimming areas. Each beach area was divided into quarters or sectors; each having 3 or 4 sampling locations associated with it. These figures have been provided as examples of study maps and do not provide exhaustive information or show all locations examined.

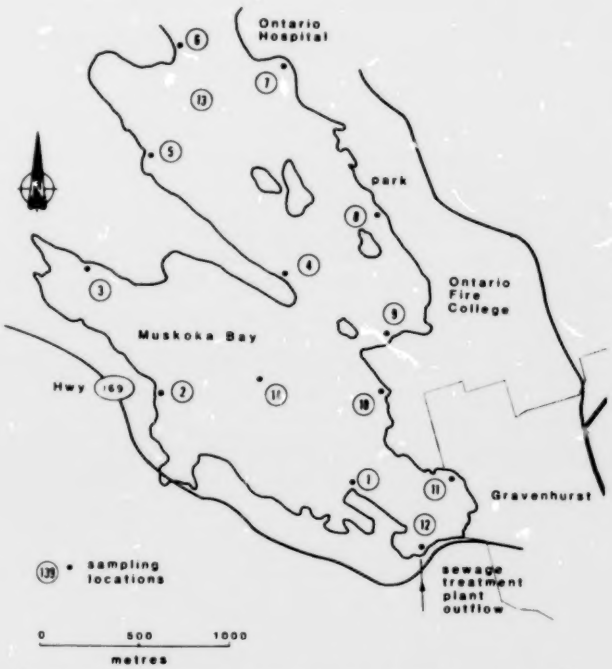

Figure 2: Sketch map of Muskoka Bay showing sampling locations and major geographic features.

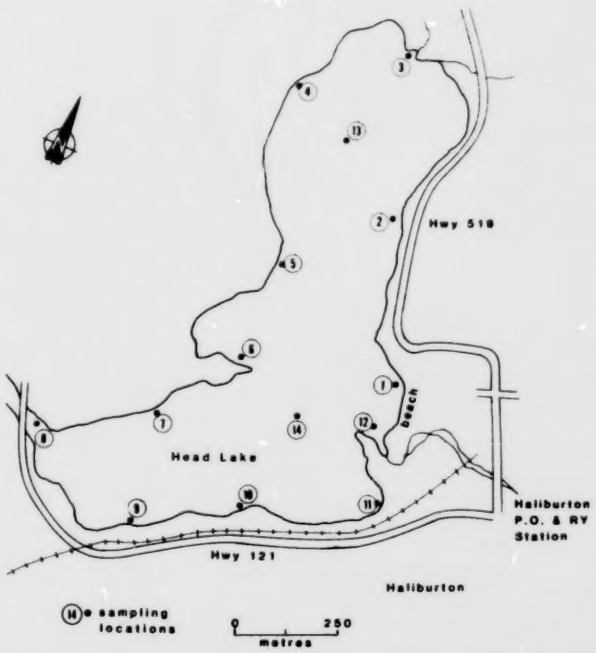

Figure 3: Sketch map of Gull Lake showing sampling locations and major geographic features.

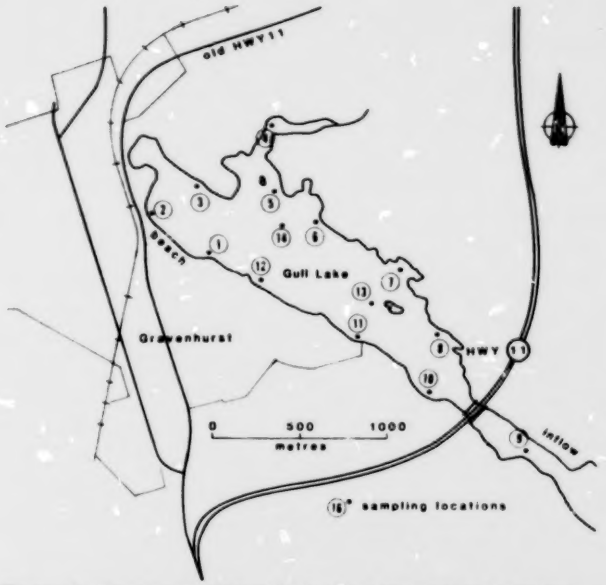

Figure 4: Sketch map of Head Lake showing sampling locations and major geographic features.

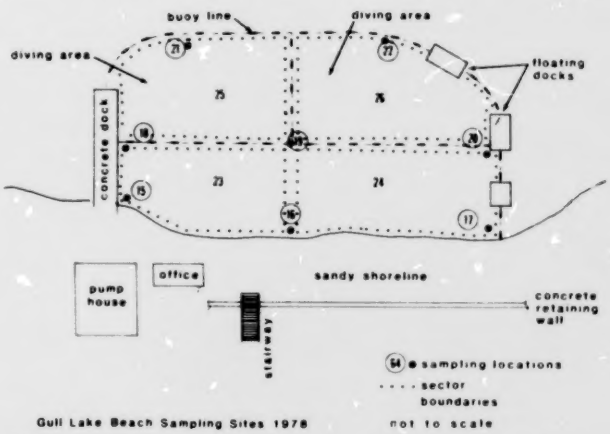

Figure 5: Sketch map of Gull Lake beach in Gravenhurst showing sampling locations and major structural features. Beach sampling locations were numbererd from 15 to 22 consecutively. Sectors were assigned the numbers 23 through 26.

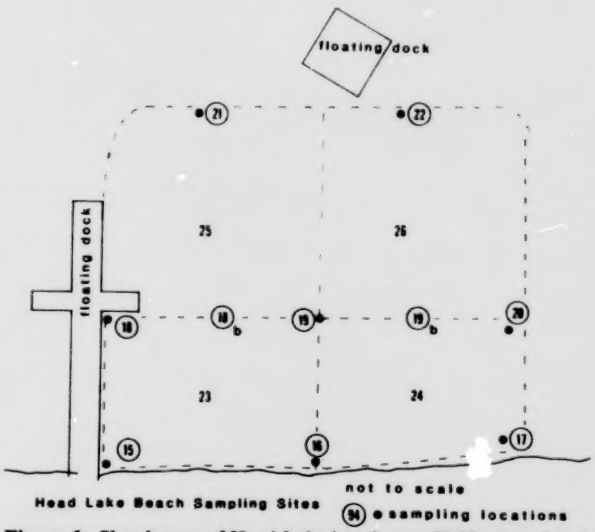

Figure 6: Sketch map of Head Lake beach near Haliburton showing sampling locations and major structural features. Beach sampling locations were numbered from 15 to 22 consecutively. Sectors were assigned the numbers 23 through 26.

3. METHODS

The field work conducted by the Microbiology Component involved two types of surveys. One consisted of regular sampling surveys of lakes to determine the distribution and densities of bacteria and levels of important nutrients. These regular sampling surveys were designed to provide information concerning the effects of development on bacteriological water quality and upon possible relationships between development, bacterial densities and nutrient status. The other type of survey entailed an epidemiological investigation of *P. aeruginosa*-related outer ear infection (*otitis externa*) among users of the shoreline waters and beaches of recreational lakes.

3.1 BACTERIAL AND CHEMICAL SAMPLING

During regular sampling surveys, which were conducted during the spring (May to June), summer (July to August) and fall (September to November) seasons, shoreline water samples were collected at a depth of one metre below the surface at established sampling locations on each study lake (Table 1). These samples were analyzed by membrane filtration procedures for indicator bacteria and for *P. aeruginosa* (Table 3).

Table 3. Microbiological analysis methods used in the Lakeshore Capacity Study (Ministry of Environment 1980).

Analysis	Medium	Temperature (°C)	Incubation time (hr)
a) *Membrane filtration*			
Total coliform (TC)	m-Endo LES agar	35	22
Fecal coliform (FC)	MacConkey membrane broth	44.5	20
Fecal streptococcus (FS)	m-Enterococcus agar	35	48
P. aeruginosa (Psa)	mPA agar	41.5	48
b) *Spread plate*			
Heterotrophic bacteria (HB)	Foot and Taylor agar	20	168
c) *Most Probable Number (MPN)*			
Fecal coliform	Lactose broth	35	48
(FC)	EC broth	44.5	24
P. aeruginosa (Psa)	Drake's broth	41.5	96
	Pseudocel agar	35	24
	King's A agar	35	24

Sediment samples were collected concurrently from the lake bottom at the same shoreline locations. These samples were analyzed by the most probable number tube-dilution methods for indicator bacteria and for *P. aeruginosa*. Composite water samples obtained from mid-lake sampling locations, were analyzed for indicator bacteria, *P. aeruginosa*, heterotrophic bacteria and for various chemicals. Generally, these samples were examined for: total Kjeldahl nitrogen, dissolved Kjeldahl nitrogen, nitrate, nitrite, ammonium, total phosphorus, total carbon, total organic carbon, inorganic carbon, pH, conductivity, colour and chlorophyll. At each sampling the secchi disk, temperature and dissolved oxygen concentration of the water at each location was recorded.

3.2 BEACH STUDIES

In 1977 a pilot project to determine the incidence of *P. aeruginosa*-related ear infections among members of organized swimming classes at Gull Lake beach and among cottagers along the shore of Muskoka Bay was initiated. In the two successive years this project was greatly intensified and additional public beaches at lakes near major communities in the study area were included as study sites. Information was gathered related to the histories of ear infection, swimming habits and the water-based recreational activities of cottagers, swimmers and non-swimmers. Physicians and hospital emergency ward staff in communities nearest the study beaches were encouraged to cooperate by providing medical information about each case of *otitis externa* treated and by supplying bacterial swab samples from the ears of their *otitis externa* patients. Participating physicians distributed questionnaires to these patients to obtain information about each patient's swimming habits and experiences with ear infection. Through personal interviews, mail-in and telephone questionnaires, information was gathered at the start and end of the swimming season from cottagers, swimmers and non-swimmers at public beaches and from medical personnel. Examples of questionnaires and relevant explanatory letters used in this study are attached as Appendix A.

Extensive sampling of the bathing beach waters as well as sampling of shoreline sediments was conducted. These samples were analyzed for indicator bacteria and *P. aeruginosa* as described for lake surveys. On each sampling day at the beaches during 1977 and 1978 the ears of swimming class members were swabbed both prior to and just after their swimming lesson. These swab cultures were analyzed for the presence of *P. aeruginosa*. Sampling of the beach waters was carried out at established stations within the designated swimming areas at intervals on each sampling day before and after known numbers of swimmers had entered the water. Air and water temperature at each sampling location and counts of the number of swimmers in the water and on the dry beach at hourly intervals were also obtained.

Information obtained from lake and beach surveys were analyzed to determine relationships between incidence of *otitis externa*, bacterial and chemical water quality, levels of human use (bather load) of water, and environmental conditions.

3.3 FURTHER IDENTIFICATION OF *P. AERUGINOSA*

Isolates of *P. aeruginosa* were retained from selected samples from water, sediment and swimmers' ears and characterized by serological typing procedures (Ministry of Environment 1980). The tube procedure employed for the testing of sediment samples and ear swabs did not give rise to distinct colonies. Therefore only one isolate was retained for each tube yielding a positive result for *P. aeruginosa*.

At present, serotyping is the most reliable method which differentiates members of a particular bacterial species on the basis of minute structural differences (Brokopp and Farmer 1979; Edmonds 1972). The serotyping procedure employed in this study led to the subgrouping of the isolates on the basis of their cell wall structures. Each trait on the cell wall has been given an assigned code, usually a number, a few letters, or a combination of both. The isolate, which possessed a particular trait, was placed in a subgroup called a 'serotype' which was identified by the trait code. Often bacteria were found to exhibit two or more traits and then they were given a serotype to indicate each trait detected.

A total of 2222 cultures of *P. aeruginosa* were retained during 1977 and 1978 for serotyping (Table 4). In 1977, of 344 cultures from lake and beach study sites, 141 originated from Gull Lake beach and 161 from Muskoka Bay. In 1978, a total of 1824 cultures were retained. Again, the majority of these originated from Gull Lake beach.

Differences in the sampling programs employed in the two years account largely for the differences seen in the numbers of isolates from each study site and source. The sediment sampling program in 1977 led to the recovery of a greater number of isolates from the sediments in 1977 than in 1978. In 1978, the intensified study at Gull Lake beach led to recoveries of greater numbers of isolates from the beach waters and the ears of swimmers than during the previous year.

In 1977, all nine cultures from samples supplied by participating physicians were acquired from the ears of *otitis externa* patients in the municipality of Gravenhurst (Table 5). In 1978 the scope of the *otitis externa* patient study was expanded into the communities of Haliburton, Huntsville, and Bracebridge. However, this increase in the number of cultures is due partly to the increase in the number of participating physicians in Haliburton, Huntsville, Bracebridge.

In 1977, sufficient materials were purchased from the University of Toronto (Professor P. Seyfried and Mr. D. Fraser) to permit the serotyping of *P. aeruginosa*. Except for a small number of cultures, all isolates retained in 1977 were serotyped. However, only a fraction of the *P. aeruginosa* isolates obtained from lake and beach waters and sediments in 1978 could be characterized serologically.

Of the 2222 isolates retained for serotyping, 1612 were typed, 1149 from water samples, 97 from the ears of swimmers and non-swimmers, and 52 from the ears of *otitis externa* patients who had been treated by area physicians.

Table 4. The number of *P. aeruginosa* cultures isolated and retained from each site studied in 1977 and 1978.

Study Site	Source of Isolation							
	Water		Sediment		Swimmer's Ears		Total	
	1977	1978	1977	1978	1977	1978	1977	1978
Deionized Water	-	1	-	-	-	-	-	1
Dwight Beach	-	5	-	-	-	-	-	5
Gull Lake	-	94	-	14	-	-	-	108
Gull Lake Beach	50	1280	78	81	13	78	141	1439
Head Lake Beach	-	13	-	-	-	-	-	13
Hidden Valley Beach	-	3	-	-	-	-	-	3
Hurricane Lake	0*	7	0	1	-	-	0*	8
Jerry Lake	0	58	0	9	-	-	0	67
Mary Lake	-	10	-	-	-	-	-	10
Mouse Lake	-	11	-	-	-	0	-	11
Muskoka Bay	55	49	101	5	5	-	161	54
St. Mary's Lake	-	11	1	-	-	-	1	11
3 Mile Lake — West	8	6	15	0	-	-	23	6
Vernon Lake Beach	-	29	-	-	-	-	-	29
Walker Lake	0*	38	7	21	-	-	7	59
Fawn Lake	0*	-	2	-	-	-	2	-
Harp Lake	0*	-	4	-	-	-	4	-
3 Mile Lake — East	0*	0*	3	0	-	-	3	0*
Lagoon	2	-	-	-	-	-	2	-
Total	115	1615	211	131	18	78	344	1824

- Study/Source not sampled
0 Study/Source was sampled but *Pseudomonas* was not encountered
0* Study/Source was sampled, *Pseudomonas* was encountered, no cultures retained.

Table 5. The number of *P. aeruginosa* cultures isolated and retained from each physician in 1977 and 1978.

Physician	Patients' Ear Isolates		Total
	1977	1978	
Haliburton Dr. #1	-	9	9
Haliburton Dr. #2	-	2	2
Haliburton Dr. #3	-	8	8
Haliburton Dr. #4	-	3	3
Huntsville Emergency Ward	-	7	7
Gravenhurst Dr. #3	3	1	4
Gravenhurst Dr. #4	2	0	2
Gravenhurst Dr. #6	1	-	1
Bracebridge Emergency Ward	-	12	12
Bracebridge Dr. #2	-	2	2
Bracebridge Dr. #9	-	1	1
Dr. Unknown	3	-	3
Total	9	45	54

- No swabs received

0 Swab received but *Pseudomonas* not encountered.

4. RESULTS AND DISCUSSION

4.1 MICROBIOLOGICAL WATER QUALITY

4.1.1 LAKES AND BACTERIAL INDICATORS

In general, the water quality of the lakes in the Muskoka-Haliburton area of Ontario appears to be good when compared to current microbiological water quality objectives. The water from these lakes should, with minimal treatment, be potable and should also be acceptable for recreational purposes.

In the study lakes, annual median total coliform levels ranged from 0 to 1000 bacteria per 100 mL. These levels compared favourably with the Ontario recreational use objective (Ministry of Environment 1978a) of 1000 total coliforms per 100 mL. However, the total coliform group is questionable as a sanitary indicator (Dutka 1973), and the acceptability of the water quality can not be absolutely proven using this group of bacteria.

The median fecal coliform levels in the study lakes ranged from 0 to 30 bacteria per 100 mL. Again, these levels compare favourably with the Ontario recreational use objectives (100 fecal coliforms per 100 mL). Greater detail about the fecal coliform levels in the various study lakes is presented in Figures 7, 8 and 9. Figure 7 presents the fecal coliform levels at the shoreline locations; Figure 8 at mid-lake locations; and Figure 9 at the inflow and outflow locations.

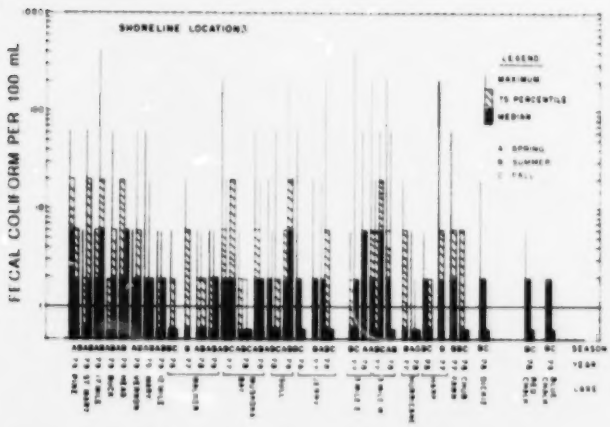

Figure 7: Plot of seasonal median, 75 percentile and maximum levels of fecal coliform per 100 mL for all shoreline locations by lake, season and year. The seasons used here are: spring (A) - May and June; summer (B) - July and August; and Fall (C) - September to November.

A year-to-year variation is suggested in most lakes. For example, Muskoka Bay sampling locations exhibited lower fecal coliform levels in 1978 than either 1977 or 1979. A seasonal variation is also suggested in most lakes with spring (May and June) or summer (September to November) usually having higher bacterial levels than fall (September to November). In general, lake inflows and outflows have the highest fecal coliform levels and the mid-lake locations have the lowest.

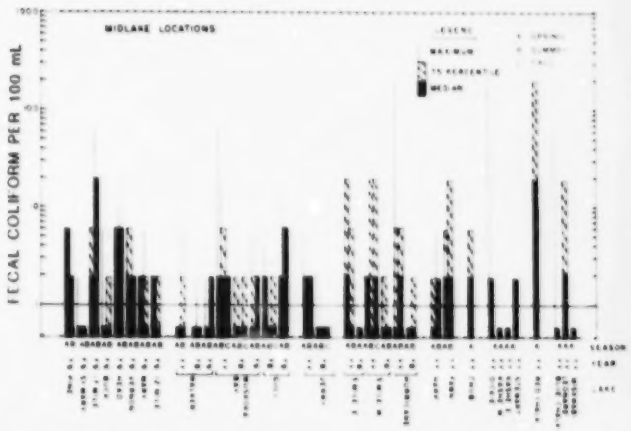

Figure 8: Plot of seasonal median, 75 percentile and maximum levels of fecal coliform per 100 mL for all midlake locations by lake, season and year. The seasons used here are: spring (A) - May and June; summer (B) - July and August; and fall (C) - September to November.

Each of these variations in fecal coliform level and the additional variations between locations, weeks, days and times within a day are expected normal variations for any of the bacteria of public health significance (Bennett 1969).

Total coliform levels (Figure 10) tended to be one to two orders of magnitude higher than the corresponding fecal

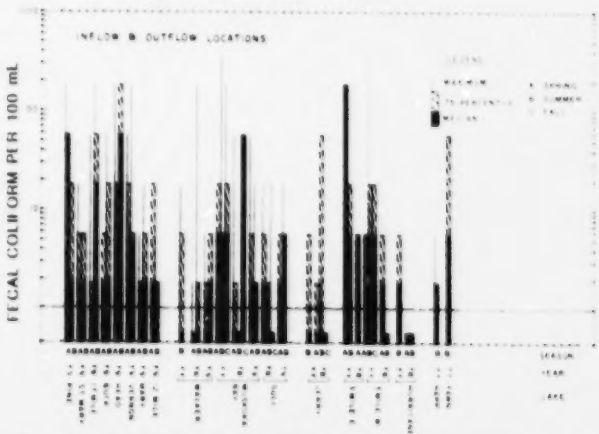

Figure 9: Plot of seasonal median, 75 percentile and maximum levels of fecal coliform per 100 mL for all inflow/outflow locations by lake, season and year. The seasons used here are: spring (A) - May and June; summer (B) - July and August; and fall (C) - September to November.

coliform levels. However, no specific relationship was apparent between total coliforms and fecal coliforms except that, as total coliform levels tended to increase, fecal coliform levels also tended to increase.

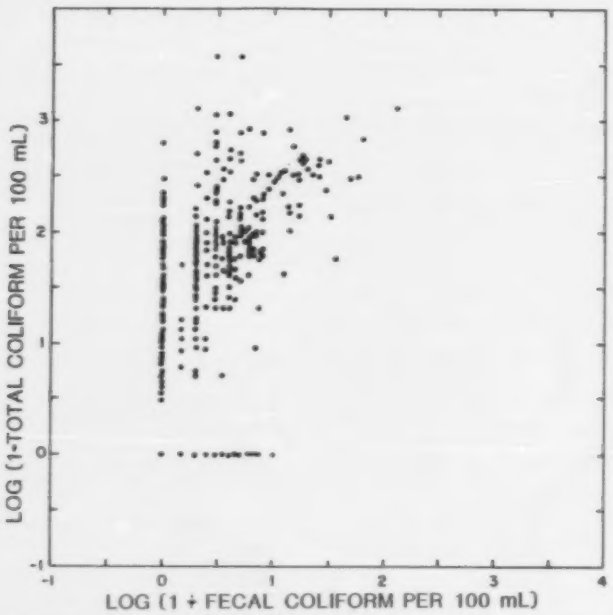

Figure 10: Plot of annual median levels of total coliforms versus fecal coliforms (on logarithmic scales) for all locations on all lakes for the years 1976 to 1979. Each point is from one location on a lake for a year.

The median fecal streptococcus levels in the study lakes ranged from 0 to 100 per 100 mL. Fecal streptococcus levels (Figure 11) tended to be approximately one order of magnitude higher than the corresponding fecal coliform levels.

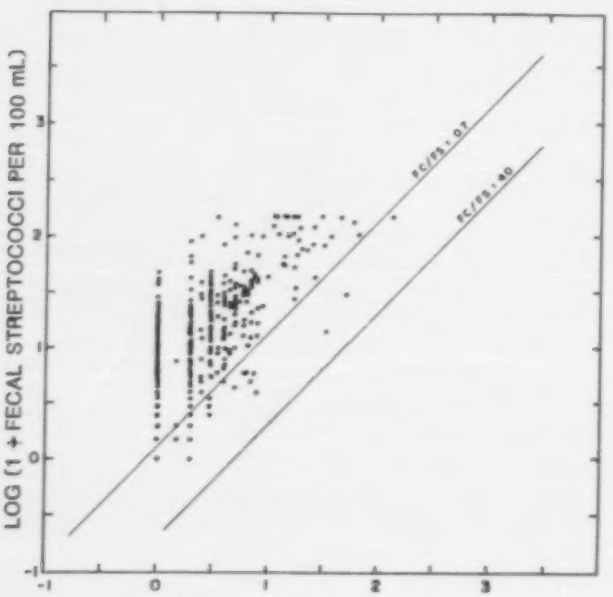

Figure 11: Plot of annual median levels of fecal coliforms versus fecal streptococcus (on logarithmic scales) for all locations on all lakes for the years 1976 to 1979. Each point is from one location on a lake for a year. The lines for fecal coliform versus fecal streptococcus ratios of 4.0 and 0.7 have been added.

Again, no specific relationship was detected between fecal coliform and fecal streptococcus levels. However, an increase in the fecal coliform levels did correspond to an increase in the fecal streptococcus levels.

In the literature, when fecal streptococcus levels are in the range of 100 per 100 mL or greater and the data represents the water quality near a source of pollution, the fecal coliform to fecal streptococcus ratio suggests the type of contamination from that source. In Figure 11, the lines corresponding to the two critical points of the fecal coliform to fecal streptococcus ratio have been drawn. On the logarithmic scale, these ratios are parallel lines with slope one and intercepts of 0.15 and –0.60 for non-human and human resources respectively. All points to the right of the human source ratio line would give a ratio greater than 4 and therefore would be expected to be from a human fecal source. All points to the left of the non-human source ratio line would give a ratio less than 0.7 and therefore would be expected to be from a non-human source. The majority of the data points were to the left of the 0.7 ratio line and most fecal streptococcus levels were below 100 per 100 mL.

In addition to the pollution indicators, samples from mid-lake locations were analyzed for heterotrophic bacteria. This procedure enumerates all bacteria requiring organic carbon as an energy source and capable of growing on a minimal low nutrient medium at a temperature of 20°C. Early work within the Lakeshore Capacity Study suggested that the levels of heterotrophic bacteria might be related to "nutrient" levels or trophic status (Hendry 1977). This conclusion is a logical extension of standard microbial ecology but further investigation of this relationship was discontinued because of other workloads within the study. However, analysis for heterotrophic bacteria on a restricted number of samples was continued. The annual median levels of heterotrophic bacteria ranged from 300 to 300,000 bacteria per mL. However, the levels greater than 10,000 heterotrophs per mL represent lakes sampled in 1977. The lakes sampled in 1978 had levels in the range 3000 to 10,000 heterotrophs per mL. This variation may have represented an actual yearly variation in heterotroph levels, but more likely reflected a lake-to-lake variation since few of the lakes examined in 1977 were also examined in 1978 or 1979 (Table 1).

4.1.2 BEACHES AND BACTERIAL INDICATORS

At the beaches total coliform levels tended to be higher than those found in the rest of the lake. Median total coliform levels ranged from 10 to 10,000 per 100 mL. The majority of these levels compared favourably with the Ontario objective for recreational use. However, some did exceed the 1000 total coliform per 100 mL.

The fecal coliform levels at the beaches also tended to be higher than those found in the rest of the lake. However, most levels did compare favourably with the Ontario recreational use objective. Fecal coliform levels ranged from 0 to 100 per 100 mL. The relationship between the total coliform and fecal coliform levels at the study beaches is presented in Figure 12. As was seen in the lake sampling, no specific relationship was detected between total coliform and fecal coliform levels.

The median fecal streptococcus levels found at the study beaches ranged from 0 to 500 per 100 mL with the majority of levels between 10 and 100 per 100 mL. These levels tended to

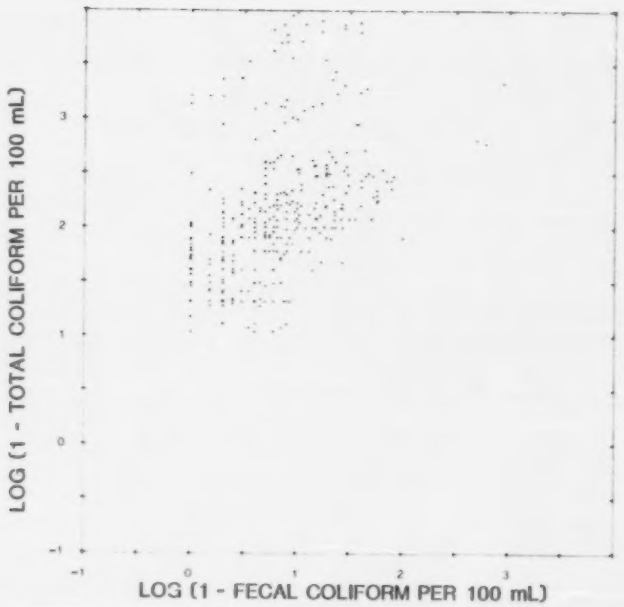

Figure 12: Plot of median levels of total coliforms versus fecal coliforms (on logarithmic scales) for all sectors of the beaches and all observation times for 1979.

be slightly higher than corresponding levels at other locations on the lake. Figure 13 presents the relationship between fecal coliform and fecal streptococcus levels as found at the study beaches. The fecal streptococcus levels generally were higher than the fecal coliform levels suggesting a non-human source of pollution.

4.1.3 OCCURRENCE OF *PSEUDOMONAS AERUGINOSA* — LAKES AND BEACHES

The bacterium *P. aeruginosa* has been described as "a ubiquitous organism, able to flourish in multiple environments, ...to survive for lengthy periods as long as sufficient moisture is available" (Young 1977). In the study lakes, *P. aeruginosa* was found to be far from ubiquitous (Table 6) occurring in, at most, 20% of the lake samples. The apparent increase from 1976 to 1979 probably reflected a shift in sampling sites, in order to study locations where *Pseudomonas* played a more significant role.

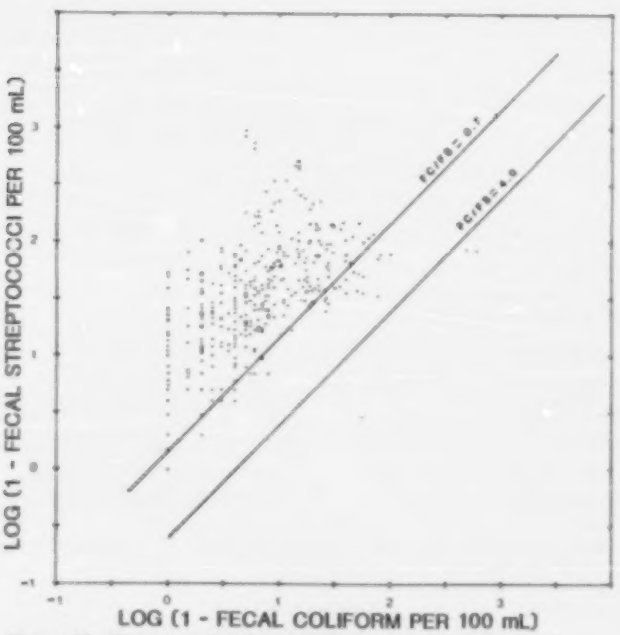

Figure 13: Plot of median levels of fecal coliform versus fecal streptococcus for all sectors of the beaches and all observation times for 1979. The lines corresponding to the fecal coliform to fecal streptococcus ratios of 4.0 and 0.7 have been added.

Table 6. Summary of the occurrence of *P. aeruginosa* in lake water samples from 24 Lakeshore Capacity Study lakes during the period 1976 to 1979.

Year	Total Number of Samples	Number of Samples Containing *P. aeruginosa* # (%)
1976	257	6 (2%)
1977	725	41 (6%)
1978	914	107 (12%)
1979	1084	217 (20%)

The levels of *P. aeruginosa* are presented in Figures 14, 15 and 16. *Pseudomonas* was not detected in the majority of samples at most locations. Occasionally samples had extremely high levels of *Pseudomonas* (e.g. 100 to 500 *Pseudomonas* per 100 mL). Seasonal variation was apparent with the summer period having the highest *Pseudomonas* levels. However, there were occasional exceptions to that general seasonal trend. Mid-lake locations (Figure 15) had higher levels of *Pseudomonas* than shoreline (Figure 14) or inflow/outflow (Figure 16) locations. Two factors affect this observation: 1) Each bar on Figure 15 generally summarizes four to eight samples, while the corresponding bar on Figure 14 summarizes twenty to eighty samples. Therefore, Figure 15 is more prone to reflect extreme case conditions. 2) At the time of analysis, the technicians noted the unusually high *Pseudomonas* levels at a mid-lake location but also noted that these high levels usually occurred shortly after or during a rainstorm. This would suggest a washing in of bacteria from an external source.

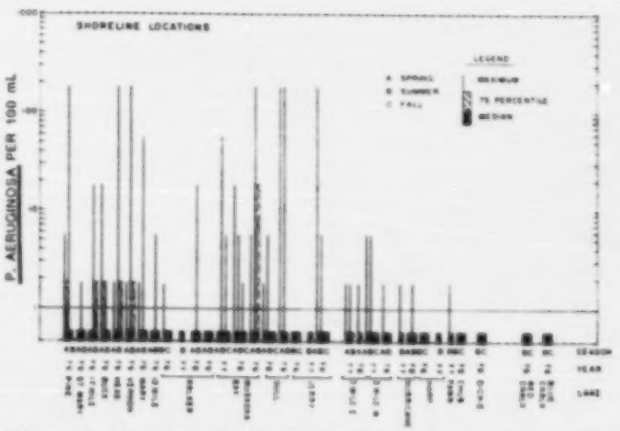

Figure 14. Plot of seasonal median, 75 percentile, and maximum levels of *P. aeruginosa* per 100 mL for all shoreline locations by lake, season and year. The seasons used are: spring (A) - May and June; summer (B) - July and August; and fall (C) - September to November.

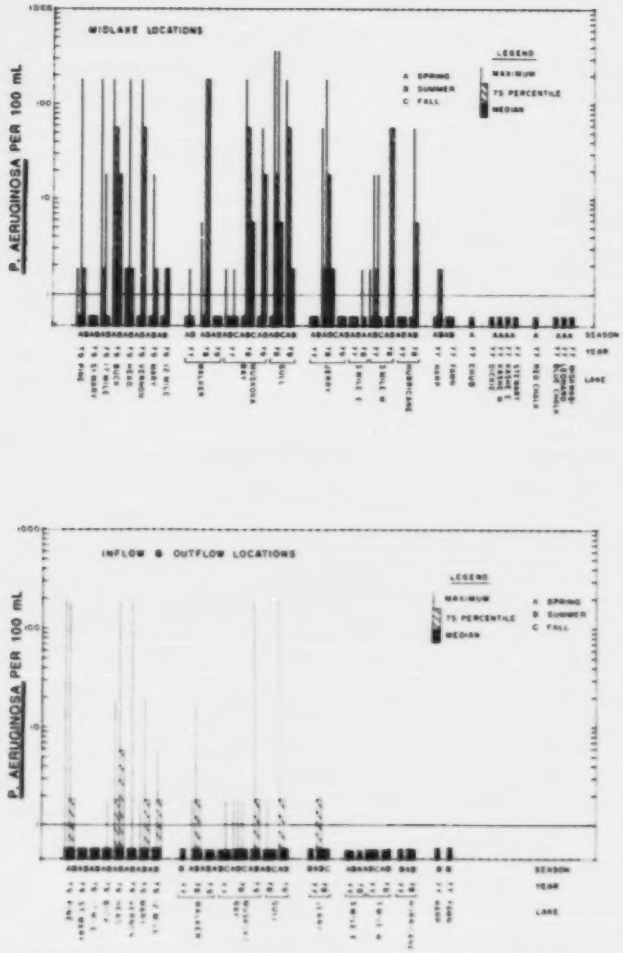

Figure 16: Plot of seasonal median, 75 percentile, and maximum levels of *P. aeruginosa* per 100 mL for all inflow/outflow locations by lake, season and year. The seasons used are: spring (A) – May and June; summer (B) – July and August and fall (C) – September to November.

P. aeruginosa was isolated from between 21 and 41 percent of the samples taken at the study beaches during 1979 (Table 7). These percentages were much higher than the 1 to 20 percent figures seen for lake shoreline (Table 6). But the majority of samples still did not contain this organism.

The levels of *Pseudomonas* were also dependent on the time of year (Figure 17). Both the frequency of isolation and the levels of *Pseudomonas* were higher in August of 1979 than in either June or July. *Pseudomonas* were usually absent during other times of the year. Single samples may have had up to 1000 *P. aeruginosa* per 100 mL.

Table 7. Numbers of samples and isolation frequency of *P. aeruginosa* at the 1979 study beaches.

Beach (1979)	Total Number of Samples	Number of Samples Containing *P. aeruginosa* # (%)
Gull	146	39 (27%)
Head	128	53 (41%)
Mary	152	41 (27%)
Pine	59	23 (39%)
Vernon	174	49 (28%)
Twelve Mile Public	64	15 (23%)
Twelve Mile Red Cross	63	13 (21%)

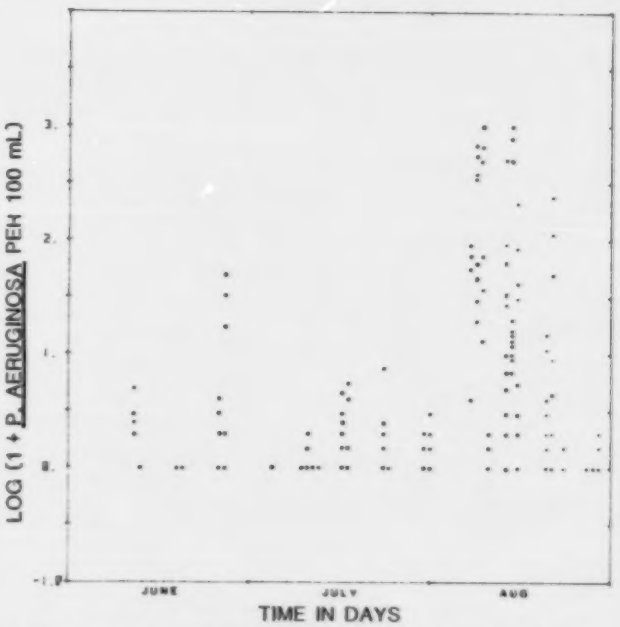

Figure 17: Time trend of *P. aeruginosa* levels observed for all sectors of the 1979 study beaches.

4.1.4 DEVELOPED VERSUS UNDEVELOPED SHORELINE

The bacterial water quality of developed shorelines with human activity, cottages, etc. were compared with that of natural shorelines with only trees, rocks and animals on the same lake or similar lakes. An undeveloped lake, Jerry Lake, has been under study for a number of years and its water quality compared with other nearby lakes. In general, the water quality at the undeveloped and the developed shorelines behaved in a similar fashion. Differences in microbiological water quality were marginal or nonexistent. Public access beaches seemed to have enough intensity of use for an impact to be measurable by the current microbiological procedures.

4.2 CHEMICAL WATER QUALITY

Table 8 summarizes in annual medium form the results of the chemical examination from the mid-lake and beach sampling locations studied in 1979. As with the microbial water quality, the chemical results did show variations from lake to lake, within the same lake at different locations and across time. Walker, Twelve Mile and Buck Lakes showed lower levels of dissolved Kjeldahl nitrogen. The difference between total and dissolved Kjeldahl nitrogen levels in Head and Buck Lakes and Muskoka Bay suggested a significant contribution from particulate material. Higher levels of nitrate and nitrite in Mary Lake, Vernon Lake and Muskoka Bay suggested a significant difference in the type of input to these lakes or possibly a greater conversion of other forms of nitrogen to nitrate by the resident bacterial population. Head and Pine Lakes had higher levels of inorganic carbon suggesting a "harder" water. Conductivity was low and only slightly higher than that of precipitation in the area. Lakes would be categorized as oligotrophic or mesotrophic.

Table 8. Water quality at mid-lake and beach locations during the 1979 sampling season (May through October). At mid-lake the median summarizes the data from two locations. At beaches, the median summarizes the data from two locations at two times on each sampling day. The number of values summarized is given at the bottom of the table.

Test	Units	Median Chemical Concentrations				
		Buck Lake	Gull Lake	Gull L. Beach	Head Lake	Head L. Beach
total Kjeldahl nitrogen	ug/L	234	345	384	440	410
dissolved Kjeldahl nitrogen	ug/L	236	350	370	365	365
nitrite plus nitrate	ug/L	5	5	5	5	5
ammonium	ug/L	12	7	5.4	1.8	19.5
total phosphorus	ug/L	6.8	8.1	8.1	13.5	9.7
total carbon	mg/L	5.6	5.8	6.6	10.6	10.3
total organic carbon	mg/L	3.8	7.8	4.7	5.7	5.2
inorganic carbon	mg/L	1.7	2.0	1.8	5.1	5.1
pH	—	6.4	6.7	6.7	7.1	7.1
conductivity	micromhos/cm	34	59	59.8	74	75
water temperature	°C	20.2	20.8	21.0	21.7	22.4
dissolved oxygen	mg/L	8.8	8.6	—	8.4	—
secchi disk	m	7.8	3.4	—	3.5	—
colour	C.U.	5	5	5	12	5
chlorophyll A	ug/L	1.4	2.0	—	3.4	—
Number of values		10	22	32	18	28

— not available

Test	Units	Median Chemical Concentrations				
		Mary Lake	Mary L. Beach	Muskoka Bay	Pine Lake	Pine L. Beach
total Kjeldahl nitrogen	ug/L	329	322.5	382	312	331.3
dissolved Kjeldahl nitrogen	ug/L	316	305	320	327	287
nitrite plus nitrate	ug/L	188	185	172	17	10
ammonium	ug/L	14	15	12	11	4.1
total phosphorus	ug/L	7.4	7.4	12.1	8.8	8.7
total carbon	mg/L	6.7	6.2	6.8	7.6	7.4
total organic carbon	mg/L	5.5	5.2	4.6	4.2	4.4
inorganic carbon	mg/L	1.0	1.0	2.2	3.5	3.1
pH	—	6.5	6.6	6.9	7.0	6.9
conductivity	micromhos/cm	43	43.5	62	57	55.5
water temperature	°C	20.0	20.8	18.6	20.0	20.8
dissolved oxygen	mg/L	8.8	—	8.6	8.6	—
secchi disk	m	3.8	—	4.0	5.2	—
colour	C.U.	10	10	5	5	5
chlorophyll A	ug/L	1.8	—	37	2.0	—
Number of values		24	34	14	12	16

— not available

Test	Units	Median Chemical Concentrations				
		St. Mary Lake	17 Mile Lake	12 Mile Lake	12 Mile L. (Public)	12 Mile L. (Red Cross)
total Kjeldahl nitrogen	ug/L	268	410	237	240	282.5
dissolved Kjeldahl nitrogen	ug/L	265	265	225	215	276.3
nitrite plus nitrate	ug/L	46	15	50	32.5	10
ammonium	ug/L	14	11	10	8.5	8.5
total phosphorus	ug/L	9.4	8.6	5.2	6.4	6.1
total carbon	mg/L	6.6	5.8	6.4	6.2	5.9
total organic carbon	mg/L	5.0	3.8	3.8	3.5	3.5
inorganic carbon	mg/L	1.9	1.6	2.4	2.5	2.4
pH	—	6.7	6.4	7.1	7.0	6.9
conductivity	micromhos/cm	45	36	52	52	51
water temperature	°C	19.0	20.6	19.4	19.7	22.0
dissolved oxygen	mg/L	9.1	8.4	9.2	—	—
secchi disk	m	3.8	6.8	6.0	—	—
colour	C.U.	5	5	5	5	5
chlorophyll A	ug/L	2.2	2.0	1.6	—	—
Number of values		8	10	8	20	11

— not available

Test	Units	Median Chemical Concentrations		
		Vernon Lake	Vernon L. Beach	Walker Lake
total Kjeldahl nitrogen	ug/L	342	332.5	245
dissolved Kjeldahl nitrogen	ug/L	317	325	218
nitrite plus nitrate	ug/L	130	115	18
ammonium	ug/L	11	11	12
total phosphorus	ug/L	7.6	8.7	7.6
total carbon	mg/L	6.7	6.6	5.1
total organic carbon	mg/L	5.6	5.6	3.7
inorganic carbon	mg/L	0.9	0.9	1.3
pH	—	6.4	6.5	6.6
conductivity	micromhos/cm	38	38	36
water temperature	°C	18.8	20.0	18.0
dissolved oxygen	mg/L	8.5	—	9.2
secchi disk	m	3.0	—	5.5
colour	C.U.	15	15	5
chlorophyll A	ug/L	23	—	2.4
Number of values		24	36	10

Some variation in chemical levels can be seen between the corresponding beach and lake locations but, in general, they are the same.

4.3 EAR INFECTIONS AND HUMAN POPULATIONS

4.3.1 INTRODUCTION

Throughout the study, swimming activity was considered the same at different locations if the same number of people were using the swimming facility. The origin of the people did not affect the swimming activity. For example, the swimming activity which occurred in front of a single cottage was similar to the swimming activity which occurred at a beach available to the general public. In front of a single cottage, the swimming activity would be zero to ten people per swimming area. At a public beach the total number of people using the swimming area may be considerably higher (Figure 18). The number of people actually in the water varies with the time of day and the day of the year. More people used the swimming area from mid-July to mid-August and between the hours of 10 AM and 3 PM. A weekly pattern also existed but was easily altered by climatic conditions.

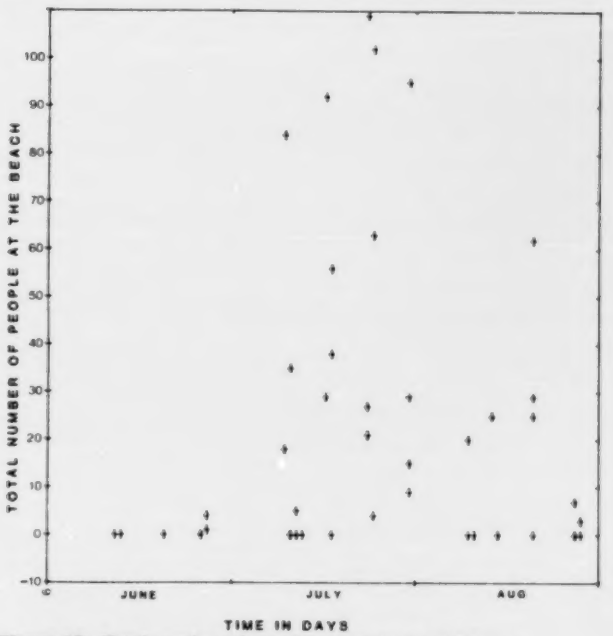

Figure 18: Total number of people at a study beach at any particular time related to the time of year during the summer of 1979. All beach studies are represented in this graph.

Table 9. Age distribution of respondents to the 1977, 1978 and 1979 questionnaires. Column labelled "Ear Infection" show age distribution of those reporting ear infections. "General Response" shows the age distribution across a number of study locations for that year.

Age Range (years)	Age Distribution							
	1977*		1978			1979		
	Muskoka Bay	Gull Lake Beach	General Response		Ear Infection	General Response		Ear Infection
0-4	4%	0%	1%	-	-	9%	(13%)	16%
5-14	13%	93%	47%	(15%)	71%	40%	(12%)	61%
15-24	21%	7%	17%	(8%)	13%	17%	(4%)	10%
25-34	16%	-	9%	(9%)	8%	14%	(4%)	8%
35-44	11%	-	11%	(2%)	3%	8%	(1%)	1%
45-54	12%	-	5%	(10%)	5%	4%	(2%)	1%
55-64	13%	-	4%	-	-	2%	(4%)	1%
65-74	6%	-	4%	-	-	3%	(3%)	1%
75-84	1%	-	1%	-	-	1%	-	-
No answer	4%	-	1%	-	-	-	-	-
Total number of individuals	531	55	380		38	1042		79

(%) = the percentage of the respondents in that category which also reported an ear infection.

- = not applicable.

* = No ear infections reported in 1977.

By using these two situations, the cottage and beach, the study was examining swimming activities where the swimmer density varied from very low to moderate use.

Table 10. Summary of response to the 1977 Muskoka Bay questionnaire.

Question	Yes %	No %
Male	50	—
Female	50	—
Frequency of water contact		
less than 3 times per week	33	—
3-5 times per week	22	—
more than 5 times per week	29	—
did not swim	12	—
Swimming location		
cottage	74	—
other locations on lake	8	—
pools	2	—
others	8	—
Wear ear plugs or bathing cap	—	80
ear plugs	1	—
bathing cap	5	—
Wet head while swimming	74	11
Dives	51	31
Predisposition to ear infection	7	81
Total number of questionnaires	531	

— not applicable

4.3.2 1977 MUSKOKA BAY COTTAGER SURVEY

In 1977, 136 cottages were visited on Muskoka Bay and 531 people were interviewed. Of these individuals 264 were male and 265 were female. The age distribution of the people responding is given in Table 9.

The majority of people interviewed at Muskoka Bay in 1977, swam less than three times per week, and only at their cottage. They did not wear ear plugs or a bathing cap, they wet their heads while swimming, dived and they believed they were not predisposed to an ear infection (Table 10).

There were no ear infections reported in the summer of 1977 at Muskoka Bay.

Table 11. Summary of response to the 1977 Gull Lake questionnaire.

Question	Response (%) Yes	No
Male	47	—
Female	53	—
Wearing a bathing cap	0	100
Wear ear plugs	2	98
Head wet while swimming	100	0
Dive	100	0
Taking medication	33	67
Specific type of medication		
Ear infection medication	20	—
Allergy medication	6	—
Not specified	7	—
Swim at other locations frequently	76	24
Total number of questionnaires	55	

— not applicable.

4.3.3 1977 GULL LAKE SWIMMING CLASS SURVEY

In the survey conducted at Gull Lake in 1977, 55 people were interviewed. There were 26 males and 29 females. The majority of those interviewed were in the range of 5 to 14 years (Table 9). All of the people interviewed were members of a swimming class.

The majority of the people interviewed did not wear bathing caps or ear plugs, got their head wet while they swam, dived, were not taking medication of any kind and generally swam at other locations on a frequent basis (Table 11).

There were no cases of *otitis externa* reported by the people interviewed at Gull Lake.

Table 12. Location of questionnaire interviews during 1978 and 1979.

Location	Percent of Questionnaires 1978	1979
Gull Lake Beach	47	26
Muskoka Bay	27	—
Mouse Lake	5	2
Bass Lake	4	—
Peninsula Lake	1	—
Lake of Bays	2	—
Vernon Lake Beach	2	15
Mary Lake Beach	2	19
Head Lake Beach	8	9
Pine Lake Beach	—	12
Twelve Mile Lake Beach Red Cross	—	15
Twelve Mile Lake Beach Public	—	1
Unclassified	2	—
Total number of questionnaires	380	1042

— not applicable.

Table 13. Summary of response to the 1978 swimmer questionnaire.

Question	General Response Yes		No		Response of those reporting an ear infection Yes	No
Male	44%	(8%)	—		34%	—
Female	56%	(12%)	—		66%	—
Dive	71%	(11%)	24%	(8%)	79%	18%
Swim under water	82%	(11%)	13%	(4%)	92%	5%
Wear a bathing cap	5%	(10%)	90%	(10%)	5%	92%
Wet head while swimming	86%	(11%)	9%	(3%)	95%	3%
Wear ear plugs	2%	(13%)	93%	(10%)	3%	95%
Previous infection	37%	(26%)	59%	(1%)	95%	5%
Often ear infection	4%	(44%)	91%	(9%)	18%	82%
Infection this summer	10%		—		—	—
Associate infection this summer with swimming	7%	(93%)	16%	(16%)	68%	26%
Seek medical treatment	6%	(90%)	18%	(27%)	50%	47%
Ever hospitalized	2%	(11%)	40%	(24%)	3%	95%
Medication prior to symptoms of ear infection	—	—	25%	(39%)	—	97%
Total number of questionnaires	380				38	

(%) the percentage of the respondents in that category which also reported an ear infection.

— not applicable.

4.3.4 1978 SWIMMER QUESTIONNAIRE

In 1978, 380 people were interviewed at various locations (Table 12). Of these, 214 (56%) were female and 166 (44%) were male (Table 13). Sixty-five percent of the people interviewed were 24 years old or younger (Table 9).

The majority of the general population did not swim in May or June. However, the frequency of swimming did increase in July and August. A large portion of the people said they swam 10 or more hours per week in July and August (Table 14).

Table 14: Distribution of ear infections and swimming frequency during May, June, July and August of 1978.

Swimming Frequency Response	May			June			July			August		
	General		% ear	General		% ear	General		% ear	General		% ear
Did not swim	69%	(10%)	66%	35%	(8%)	29%	4%	-		3%	-	
Occasionally	19%	(13%)	24%	28%	(8%)	21%	16%	(2%)	3%	17%	(2%)	3%
Frequently	9%	(9%)	8%	26%	(14%)	37%	38%	(8%)	31%	39%	(8%)	31%
Very Frequently	1%	(20%)	2%	9%	(15%)	13%	40%	(16%)	66%	39%	(17%)	66%
No answer	2%	-		2%	-		2%	-		2%	-	

Occasionally 0-2 hrs./wk., Frequently 3-10 hrs./wk., Very frequently 10 or more hrs./wk.
(%) = the percentage of the respondents in that category which also reported an ear infection.
- = not applicable
% ear = response of those reporting an ear infection.

Of the 380 people interviewed, most of them said they dived, swam underwater, got their heads wet while swimming and did not wear a bathing cap or ear plugs (Table 13). One hundred nineteen people (37%) had a previous ear infection and 16 people (4%) reported that they often experienced ear infections. The majority of the general population had never been hospitalized for an ear infection at any time.

In 1978, 38 people (10%) of the total 380 people interviewed reported having an ear infection during the summer. Of these, 25 (66%) were female and 13 (34%) were male. Seventy-one percent of the people reporting ear infections were 5 to 14 years old (Table 9). Of the people reporting ear infections, the majority dived, swam underwater, got their head wet while swimming and did not wear a bathing cap or ear plugs.

Thirty-six (95%) of the 38 people reporting ear infections had previously experienced ear infections but this majority also reported that they did not often experience ear infections. Sixty-eight percent of the people did not associate their ear infection with their swimming activity, and most of the people sought medical treatment for their ear infection in the summer of 1978. A large number of the people with ear infections were never hospitalized for these and were not taking medication for another ailment at the time the symptoms of the ear infection appeared.

The majority of the population experiencing ear infections, did not swim in May, swam frequently (3 to 10 hours per week) in June and swam very frequently (10 or more hours per week) in July and August (Table 14). The highest percentage of the people with ear infections in the summer of 1978 experienced them in August (42%). Twenty-six percent of the ear infections occurred in July.

4.3.5 1979 SWIMMER QUESTIONNAIRE

In 1979, a total of 1042 people were interviewed at 8 different locations (Table 12). Six hundred forty (61%) were female and 402 (39%) were male (Table 15). More than half of the people interviewed were 24 years or younger (Table 9).

Table 15. Summary of response to the 1979 swimmer questionnaire.

Question	General Response				Response of those reporting an ear infection	
	Yes		No		Yes	No
Male	39%	(8%)	—		42%	—
Female	61%	(7%)	—		58%	—
Head wet while swimming	87%	(8%)	12%	(3%)	96%	4%
Swimming class	32%	(13%)	67%	(5%)	56%	44%
Untreated water for washing	19%	(4%)	44%	(13%)	20%	33%
Previous ear infection	26%	(27%)	74%	(1%)	90%	10%
Ever treated for an ear infection	22%	(26%)	72%	(2%)	79%	20%
Ever been hospitalized for an ear infection	2%	(44%)	91%	(7%)	10%	81%
Ever treated yourself for an ear infection	6%	(28%)	87%	(6%)	22%	71%
Ear infection this summer	8%		—		—	—
Treated this summer	6%	(94%)	87%	(2%)	73%	22%
Associate with swimming activity	11%	(38%)	75%	(4%)	54%	38%
Regularly swim at more than one beach	66%	(8%)	32%	(46%)	68%	32%
Total number of questionnaires	1042				79	

(%) the percentage of the respondents in that category which also reported an ear infection.
— not applicable.

The majority of the general population swam very frequently (4 or more times per week), got their heads wet while swimming, were not enrolled in a swimming class and did not use untreated water for washing or bathing (Tables 15, 16). Most of the general population did not experience a previous ear infection, were never treated by a doctor or hospitalized for an ear infection, never tried to treat themselves for an ear

infection, and said they were not treated for an ear infection that summer. Most of the people interviewed swam at more than one beach.

In 1979, 79 people (8%) of the 1042 interviewed reported experiencing an ear infection. Of these, 46 (58%) were female and 33 (42%) were male (Table 15). Seventy-five percent of the people experiencing an ear infection were 14 years or younger (Table 9). Most of the people experiencing an ear infection swam very frequently (4 or more times per week), got their head wet while swimming and were members of a swimming class. Seventy-one (90%) of those reporting an ear infection had experienced a previous ear infection. The majority of the infected population were treated at some time for a previous ear infection. Most of the people had never been hospitalized and had never tried to treat themselves for an ear infection.

Table 16. The frequency of swimming activity of the general population and those reporting an ear infection in 1979.

Frequency of swimming	Response: General Population		Those Reporting Ear Infection in 1979
Did not swim	5%	(2%)	1%
Occasionally	20%	(2%)	5%
Frequently	18%	(7%)	17%
Very frequently	56%	(10%)	77%

Occasionally = 1-2 ×/week, less than 1 hour
Frequently = 1-4 ×/week
Very frequently = 4 or more times/week
(%) = the percentage of the respondants in that category which also reported an ear infection.

Of the people experiencing an ear infection in the summer of 1979 the majority were treated for their ear infection. Most of the people associated their ear infection with their swimming activity and most swam regularly at more than one beach.

Forty-six percent of the ear infections occurring in the summer of 1979 were in the month of July, eighteen percent in June and a considerably smaller number (6%) occurred in August.

4.3.6 THE *OTITIS EXTERNA* PATIENT SURVEYS OF 1978 AND 1979

In 1978, a total of 79 cases of *otitis externa* were reported by participating physicians in 4 communities (Table 17). In 1979, a total of 114 cases were reported by physicians in 5 communities.

Table 17. Summary of communities responding to patient questionnaires in 1978 and 1979.

Location	Patients Only 1978	Patients Only 1979	Physician Only 1978	Physician Only 1979	Complete data* 1978	Complete data* 1979	Total 1978	Total 1979
Bracebridge	4	1	3	0	1	5	8	6
Bracebridge Emergency	0	2	6	3	14	10	20	15
Huntsville Emergency	3	1	5	1	7	20	15	22
Huntsville	0	1	1	1	2	13	3	15
Haliburton	0	0	1	4	28	17	29	21
Gravenhurst	0	1	3	0	1	0	4	1
Minden	-	2	-	7	-	25	-	34
Total	7	8	19	16	53	90	79	114

\- not applicable
* Both Patient and Physician responses

Table 18 indicates the age distribution of the patients in 1978 and 1979. The majority of the patients experiencing an ear infection were between the ages of 5 and 24 years.

Table 18. Summary of age distribution for 1978 and 1979 *otitis externa* patient surveys.

Age Group (years)	Number of People (%) 1978	1979
0-4	3	1
5-14	47	64
15-24	30	22
25-34	7	3
35-44	8	8
45-54	3	0
55-64	0	1
65-74	0	0
75-84	2	0
NA	0	2
Total number	60	98

Table 19 presents the general response to the questions on both the 1978 and 1979 patient questionnaires. In 1979, 97 people responded to the patient questionnaire and in 1978, 60 people responded. In both years male patients outnumbered female patients. The majority of the patients in both years dived, swam underwater, wet their head while swimming and did not wear a bathing cap or ear plugs. Almost half the people responding in 1978 and 1979 said thay had experienced a previous infection and the majority of the patients associated their ear infection with their swimming activity.

Table 19. Summary of response to the *otitis externa* patient questionnaire of 1978 and 1979.

Response	1978 Yes (%)	1978 No (%)	1979 Yes (%)	1979 No (%)
Male	57	—	59	—
Female	43	—	41	—
Dive	80	17	77	21
Swim underwater	92	5	95	3
Bathing cap	0	97	1	97
Wet head	93	2	97	1
Ear plugs	2	92	3	95
Previous infection	50	45	51	47
Associate infection	75	17	85	13
Hospitalized	—	—	5	93
Ever treated	—	—	22	76
Treated without medical advice	—	—	13	85
Untreated water	—	—	51	47
Swimmer	—	—	99	1
Often swimming:				
per week 1-7 x	62	—	—	—
8-15 x	8	—	—	—
+16 x	25	—	—	—
Length of time in water per swim:				
1/4-1 hr.	43	—	—	—
1-3 hrs.	53	—	—	—
Total number of questionnaires	60		97	

Most of the patients in 1979 had never been hospitalized for an ear infection and had never treated themselves for an ear infection with medication prescribed for a previous ear infection. Eighty-five percent of the patients in 1979 indicated they had never tried to treat themselves for an outer ear

infection without obtaining medical advice. About one-half of the patients indicated that they used untreated lake or river water for washing or bathing.

4.4 RELATIONSHIP BETWEEN *P. AERUGINOSA* AND OTHER VARIABLES

In the *P. aeruginosa* model, certain variables were suggested to have some relationship with the levels of *Pseudomonas* in water. These variables were suggested because the literature indicated that a relationship existed or because general microbiology principles indicated that a relationship could exist. The prime variables were: 1) some measure of human user density, e.g. total people at the beach, because this would be the source of the bacteria; 2) the water temperature, because growth/survival of the bacteria was favoured by warm temperatures and 3) some measure of nutrients, because these would be needed by the bacteria if they were to grow.

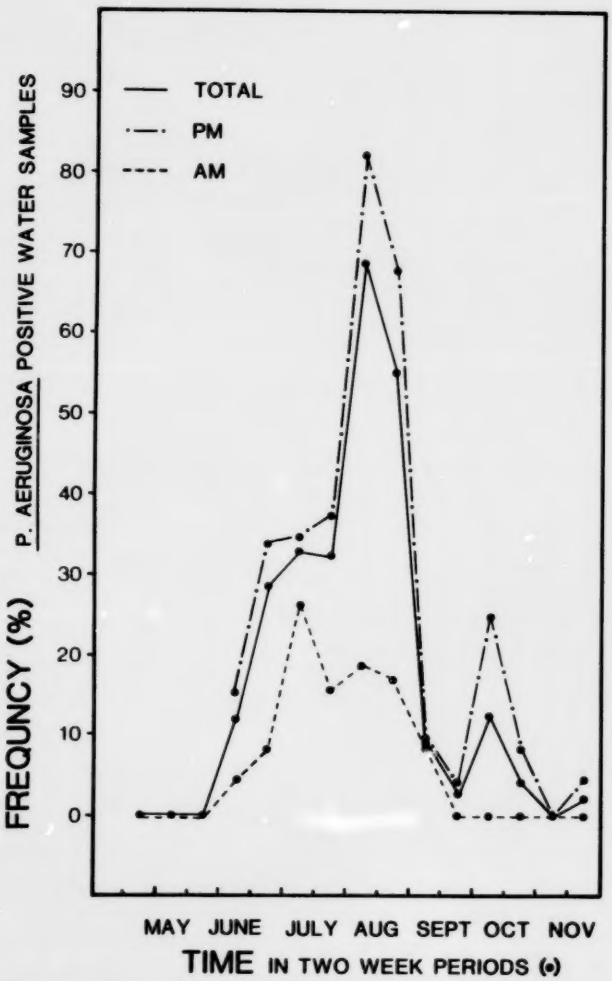

Figure 19: Time trend of the frequency of isolation of *P. aeruginosa* from water samples during 1978 at Gull Lake beach.

For each two week period during 1978, the water samples were categorized as samples taken prior to the daily use of the beach, usually in the morning (AM) or samples taken after the beach had been used (PM).

The third category (TOTAL) contained all samples. Each line summarizes the percentage of samples in the category which contained *Pseudomonas*.

The results from the 1978 Gull Lake beach study seemed to confirm the preconceived relationships in a qualitative way. The frequency of isolation of *P. aeruginosa* from the water at the beach followed a peaked time trend (Figure 19) with maxium values attained in late July and early August rising in early June and declining in early September. The numbers of users (Figure 20) of the beach followed a similar time trend to the *Pseudomonas* frequency of isolation and also showed a similar diurnal variation since *Pseudomonas* was more frequently isolated in the afternoon than the morning. This time trend was also repeated in water temperatures (Figure 21). Therefore, at least two variables, number of beach users and water temperature, could be related to *P. aeruginosa* levels.

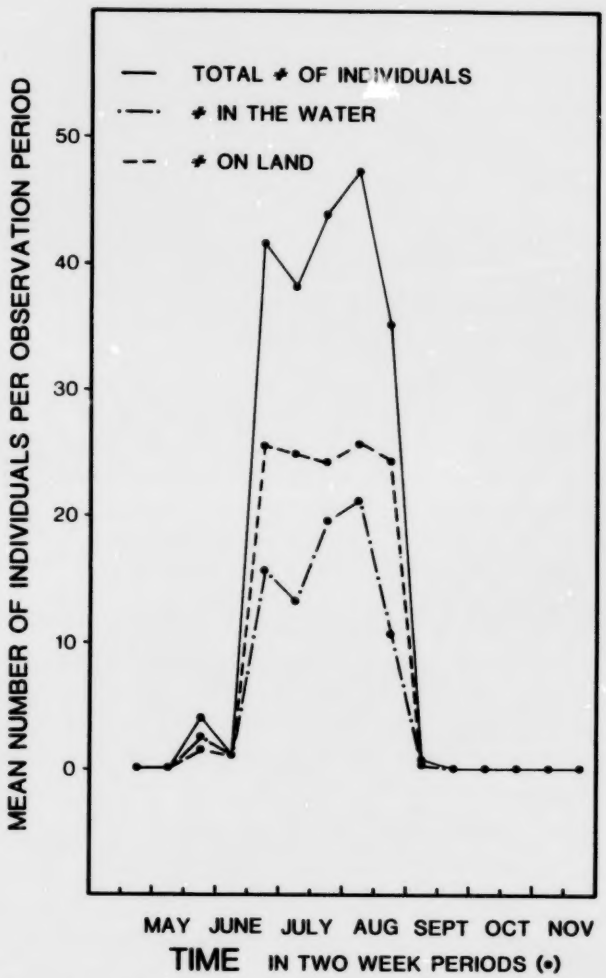

Figure 20: Time trend of the use of Gull Lake beach during 1978. The lines represent the total number of individuals at the beach, the numbers who were physically in the water at the time the tally was taken and the number on the sand part of the beach. The mean number for each two week period is given but the extremes are in the range 0 to 120 individuals.

The Gull Lake beach results were then examined statistically utilizing standard transformations of the data and a stepwise multiple linear regression. The multiple regression procedure revealed (equation A on Table 20) that the logarithm of the *Pseudomonas* level was related to the water temperature, the total number of users of the beach in the previous hour and the logarithm of the fecal coliform level. The variable, fecal

coliform, was the least significant variable in the equation but did fit the inverse relationship suggested in the literature (Mucha et al 1969).

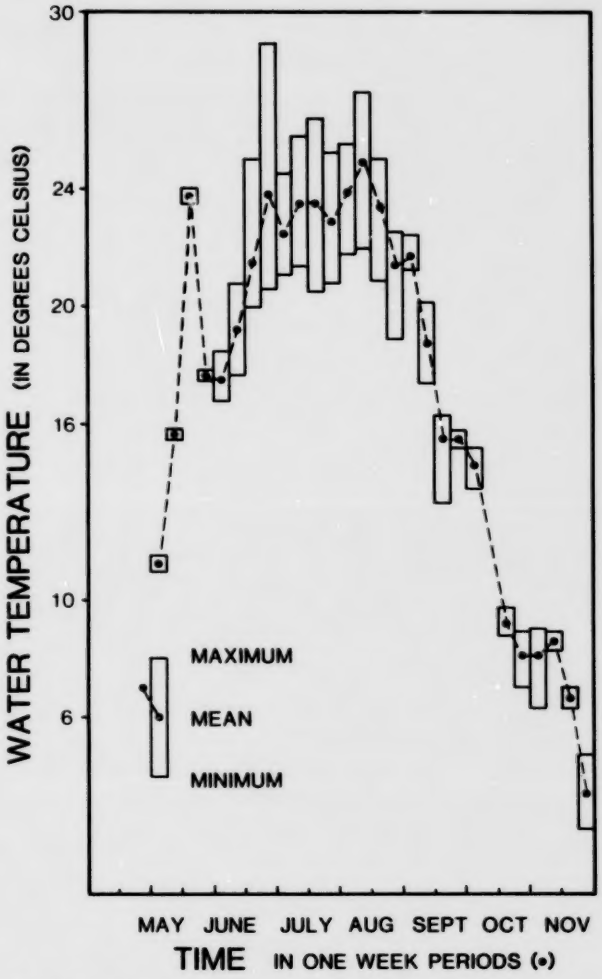

Figure 21: Time trend of the water temperature at Gull Lake beach during 1978. Mean maximum and minimum water temperatures for each one week period are shown.

The 1979 results followed similar time trends to the 1978 results. Some of the beaches showed a secondary maximum in frequency of *Pseudomonas* isolations in July. However, using the multiple regression procedure, the equations B through F (Table 20) were derived. No two of the equations showed the same significant variables. Many of the relationships were hard, if not possible, to explain. The relationships did not fit a model.

Examination of some of the underlying statistics did provide some answers to the non-uniformity of multiple linear regression relationships. The multiple linear regression assumed that all variables were either normally distributed or were transformed to be so. The logarithmic transformation is commonly assumed to normalize microbiological data. However, the low level bacterial densities present in this study were not distributed according to a log normal distribution but were distributed according to a truncated log normal distribution. The truncated log normal distribution arose because all results in the lower tail of the distribution are reported as no bacteria detected in a given volume of sample. No *P. aeruginosa* was detected in up to 90% of 100 mL samples taken from specific locations. Similar statements can be made for fecal coliform and in some cases fecal streptococcus levels.

All of the evidence from the Lakeshore Capacity studies did suggest that a relationship existed between *P. aeruginosa*, the number of people using the beach, and the water temperature but the relationship could not be statistically validated. *P. aeruginosa* tended to increase as the numbers of users of the beach increased. *Pseudomonas* could not usually be isolated where the users from single cottages utilize a shoreline but could usually be isolated at heavily used beaches. The relationship fit the literature statement that *Pseudomonas* can be isolated in "northern temperature surface waters" only if the water was "recently affected by human activity or the activities of domestic animals" (Hoadley 1977).

Increasing water temperature seemed to increase the levels of *Pseudomonas* by providing a mechanism for the bacterium to either survive for a longer period of time or to grow. This relationship is also suggested in the literature (Hoadley 1977).

Table 20. Relationship of *P. aeruginosa* with other variables measured in the water and at the beach. All of the equations were developed using the stepwise multiple linear regression procedure until all remaining variables were not significantly related to the developing equation.

Location	Equation	Statistics r^2	F	d.f.
Gull Lake Beach 1978	A $\log(1 + PsA) = -0.72 + 0.041\ WTEMP - 0.164 \log(1 + FC) + 0.0048\ TPREV$	0.24	10.9	3, 100
Gull Lake Beach 1979	B $\log(1 + PsA) = -2.36 + 0.0047\ BPREV - 0.0005\ DTKN + 0.044\ COND$	0.33	6.61	3, 39
Pine Lake Beach	C $\log(1 + PsA) = -1.415 + 1.044 \log(1 + TC) + 0.022\ TPREV$	0.92	77.3	2, 13
Vernon Lake Beach	D $\log(1 + PsA) = -49.27 - 0.21\ DAY - 0.031\ BPREV + 0.251\ TP - 0.008\ DTKN + 0.616\ pH - 6.87\ COND$	0.93	39.8	6, 19
Head Lake Beach	E $\log(1 + PsA) = -11.44 + 0.483 \log(1 + TC) + 0.046\ NO_3 + 0.136\ COND$	0.93	132.3	3, 32
12 Mile Red Cross Beach	F $\log(1 + PsA) = -0.32 + 0.016\ ATEMP$	0.23	4.29	1, 14

PsA = *P. aeruginosa*/100 mL
TC = Total coliform/100 mL
FC = Fecal coliform/100 mL
TPREV = Total people in previous hour
BPREV = Bystanders in previous hour
WTEMP = Water Temperature (degrees Celsius)
ATEMP = Air Temperature (degrees Celsius)
COND = Conductivity (micromhos/cm)
DTKN = Dissolved total Kjeldahl nitrogen (ug N/L)
DAY = Day of year (January 1 is 1)
TP = Total phosphorus (ug P/L)
pH = log hydrogen ion concentration
NO_3 = nitrate plus nitrite (ng N/L)

Water temperature also probably affected *Pseudomonas* via user preference.

4.5 *PSEUDOMONAS AERUGINOSA* IN EARS

In 1978, as part of the intensive study of Gull Lake beach, the swimming class members were asked to participate in a study of the occurrence of *P. aeruginosa* in their ears. After obtaining the appropriate permission, swabs were taken both from ears of the swimmers before they went in swimming and immediately after swimming. These swabs were then analyzed for *P. aeruginosa*.

The time trend of *Pseudomonas* found in swimmer's ears (Figure 22) followed closely that of *Pseudomonas* found in water (Figure 19). Low frequencies of isolation were observed in June and July with much higher frequencies in early August.

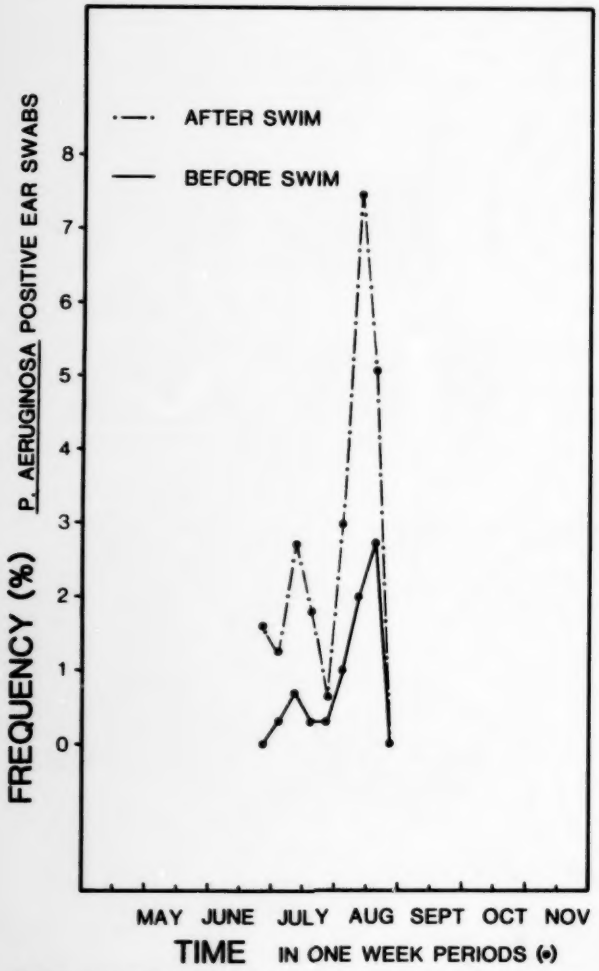

Figure 22: Time trend of frequency of isolation of *P. aeruginosa* from ear swabs of swimmers before and after swimming at Gull Lake beach during 1978.

Since the same swimmers' ears were swabbed both before and after swimming and over a number of days, the occurrence of *P. aeruginosa* in the ear could be followed over time. Some *Pseudomonas* were isolated prior to swimming from ears without any apparent signs of disease. Certain individuals had *Pseudomonas* present in an ear over an extended period of time. This apparent carrier state of an otherwise healthy individual is also confirmed in the literature (Seyfried and Fraser 1978; Young 1977). The original source of the *Pseudomonas* resulting in the carrier state cannot be determined. But the carrier state would form a source for *Pseudomonas* contamination of the beach waters.

More *Pseudomonas* were present in the ears after swimming than before. The duration of the swimming activity would be one and possibly two hours. Therefore, growth of the organism in the ear can probably be ruled out during this short period. The only source of the new *Pseudomonas* in the ears was water contaminated with *Pseudomonas* which gained access to the ear during swimming. Having gained access to the ear, the *P. aeruginosa* could go to the next step and cause ear infection

These data show that if the water in a swimming area contains *P. aeruginosa*, swimming activity will introduce the *Pseudomonas* into the ear of the swimmer. Whether that *Pseudomonas* will cause an ear infection will depend on a number of medical circumstances which are beyond the scope of this study.

Table 21. Frequency of *P. aeruginosa* serotypes in lake water, sediment, swimmers' ears and *otitis externa* patients' ears.

Serotype	Frequency for Source of Isolates (percent of source total)					
	Water	Sediment	Swimmers Ears	Patients Ears	Total	(Total No. Serotypes)
Untypable	13.4	14.6	6.2	15.4	13.3	(214)
0:1	10.8	9.2	10.3	13.5	10.5	(170)
0:11	10.1	6.7	3.1	3.8	8.8	(142)
0:4	7.6	7.6	3.1	5.8	7.3	(117)
0:6	5.1	7.6	6.2	5.8	5.7	(92)
0:5d	6.1	3.2	1.0	1.9	5.1	(82)
0:3, 4, 9, 10	5.9	1.3	0.0	0.0	4.5	(72)
0:10	4.4	1.3	6.2	5.8	3.9	(63)
0:6, 10	1.4	12.1	1.0	5.8	3.6	(58)
0:3, 4, 6, 9, 10	4.3	1.3	0.0	0.0	3.3	(53)
Self Agglutination	2.8	0.3	5.2	11.5	2.7	(44)
0:7	2.1	5.4	1.0	0.0	2.6	(42)
0:6, 10, 5d	1.7	4.5	3.1	1.9	2.3	(37)
0:3	1.6	1.9	6.2	7.7	2.1	(34)
0:4, 6, 9, 10	1.5	0.3	0.0	0.0	1.1	(18)
0:3, 4, 6, 10, 5d	1.0	0.0	3.1	3.8	1.0	(16)
0:9	1.1	1.0	0.0	0.0	1.0	(16)
0:4, 9, 10	1.4	0.0	0.0	0.0	1.0	(16)
0:10, 5d	0.5	2.5	1.0	0.0	0.9	(15)
0:1, 4	0.4	2.5	0.0	0.0	0.8	(13)
0:3, 4, 10, 5d	0.3	0.0	6.2	3.8	0.7	(12)
0:9, 10	1.0	0.0	0.0	0.0	0.7	(12)
0:4, 6	0.6	1.0	1.0	0.0	0.7	(11)
0:5c	0.0	3.2	0.0	0.0	0.6	(10)
0:4, 7, 9	0.9	0.0	0.0	0.0	0.6	(10)
0:7, 9, 10	0.4	1.6	0.0	0.0	0.6	(10)
0:4, 5d	0.5	0.0	3.1	0.0	0.6	(9)
0:7, 9	0.7	0.3	0.0	0.0	0.6	(9)
0:4, 7, 9, 10	0.7	0.0	0.0	0.0	0.5	(8)
0:3, 4, 7, 9, 10	0.6	0.3	0.0	0.0	0.5	(8)
Source Total	1149	314	97	52		1612

In addition to the serotypes listed in the table, the following serotypes are some which were recovered at less than 0.5 percent frequency:
(0:4, 9) (0:4, 7) (0:3, 4) (0:6, 5d) (0:4, 10) (0:12) (0:3, 6) (0:7, 10) (Psll) (0:3, 10) (0:4, 5c) (0:6, 5c) (0:10, 5c) (0:1, 7) (0:6, 12) (Sl3) (0:5c, Psll) (0:3, 5d) (0:6, 11) (0:1, 13) (0:1, 11) (0:3, 9) (0:1, 5c) (0:7, 5d) (0:8, 5d)(0:7, 8) (0:2a) (0:12, 5d) (0:11, 12) (Sl3, 5d).

4.6 IDENTIFICATION AND TYPING RESULTS FOR *PSEUDOMONAS AERUGINOSA*

Of the 1612 *P. aeruginosa* isolates serotyped (Table 21), 65.4 percent(1055) originated from Gull Lake beach. By source, 71.5 percent (822) of the water isolates, 45.5 percent (143) of the sediment isolates and 92.8 percent (90) of the ear isolates from swimmers were from Gull Lake beach.

At Gull Lake beach, serotypes 0:11 and 0:1 were the most common serotypes among the water isolates (Table 22). Serotypes 0:1 and 0:6 were most common serotypes among the sediment isolates. Serotype 0:1 was the most common serotype among the isolates from swimmers' ears. A large percentage of isolates from all sources could not be categorized because they either were untypable i.e., they did not react in the test system, or were self-agglutinating i.e., they gave a positive reaction to all tests in the system.

Table 22. Frequency of *P. aerugenosa* serotypes in beach water, sediment, and swimmers' ears at Gull Lake Beach.

Serotype	Frequency for Source of Isolates (percent of source total)					
	Water	Sediment	Swimmers Ears	Gull Lake Beach Total	Total	(Total No. Serotypes)
Untypable	10.8	15.4	6.7	11.1	13.3	(214)
0:1	13.7	10.5	10.0	13.0	10.5	(170)
0:11	13.9	5.6	3.3	11.9	8.8	(142)
0:4	3.0	7.7	3.3	3.7	7.3	(117)
0:6	6.6	9.8	6.7	7.0	5.7	(92)
0:5d	7.9	5.6	1.1	7.0	5.1	(82)
0:3, 4, 9, 10	5.4	1.4	0.0	4.4	5.1	(72)
0:10	5.5	2.1	4.4	4.9	3.9	(63)
0:6, 10	1.2	6.3	1.1	1.9	3.6	(58)
0:3, 4, 6, 9, 10	4.7	1.4	0.0	3.9	3.3	(53)
Self Agglutination	2.8	0.7	5.6	2.7	2.7	(44)
0:7	1.3	0.7	1.1	1.2	2.6	(42)
0:6, 10, 5d	2.1	1.4	3.3	2.1	2.3	(37)
0:3	1.3	0.7	6.7	1.7	2.1	(34)
0:4, 6, 9, 10	1.6	0.7	0.0	1.3	1.1	(18)
0:3, 4, 6, 10, 5d	1.3	0.0	3.3	1.3	1.0	(16)
0:9	0.4	1.4	0.0	0.5	1.0	(16)
0:4, 9, 10	1.2	0.0	0.0	0.9	1.0	(16)
0:10, 5d	0.5	4.2	1.1	1.0	0.9	(15)
0:1, 4	0.5	4.2	0.0	0.9	0.8	(13)
0:3, 4, 10, 5d	0.5	0.0	6.7	0.9	0.7	(12)
0:9, 10	0.7	0.0	0.0	0.6	0.7	(12)
0:4, 6	0.7	0.7	1.1	0.8	0.7	(11)
0:5c	0.0	6.3	0.0	0.9	0.6	(10)
0:4, 7, 9	0.0	0.0	0.0	0.0	0.6	(10)
0:7, 9, 10	0.0	0.0	0.0	0.0	0.6	(10)
0:4, 5d	0.5	0.0	3.3	0.7	0.6	(9)
0:7, 9	0.4	0.0	0.0	0.3	0.6	(9)
0:4, 7, 9, 10	0.0	0.0	0.0	0.0	0.5	(8)
Source Total	822	143	90	1055		1612

In addition to the serotypes listed in the table, the following serotypes are some which were recovered at less than 0.5 percent frequency: (0:4, 9) (0:4, 7) (0:3, 4) (0:6, 5d) (0:4, 10) (0:12) (0:3, 6) (Ps11) (0:3, 10) (0:4, 5c) (0:6, 5c) (0:10, 5c) (0:1, 7) (S13) (0:3, 5d) (0:6, 11) (0:1, 3) (0:1, 11) (0:3, 9) (0:11, 5c) (0:8, 5d) (0:7, 8) (0:5d, S13).

The most frequently encountered serotype at both shoreline and mid-lake locations was 0:4 (Table 23). At the beach locations, serotype 0:1 was most frequently isolated. Cultures which were untypable with the serotyping scheme accounted for 13.3 percent of all cultures typed. Untypable cultures were more frequent among isolates recovered from the shoreline and mid-lake locations than the beach locations. There was a higher percentage of the beach isolates which produced single serotypes. Of the *P. aeruginosa* recovered from beaches 52.2 percent produced single serotypes. Approximately 42 percent of cultures isolated from shoreline locations produced serotypes, as did 21.2 percent of cultures isolated from mid-lake locations.

Table 23. Frequency of common serotypes at various locations.

Serotype	Frequency at location (percent of location total)			
	Shoreline	Mid-lake	Beach	Total
Untypable	20.4	19.9	11.7	185
0:1	4.5	0.0	13.4	136
0:11	2.7	0.7	12.6	125
0:4	23.5	10.6	3.5	101
0:5d	0.9	2.6	7.8	79
0:3, 4, 9, 10	7.1	6.6	4.9	72
0:6	0.9	0.0	7.0	68
0:3, 4, 6, 9, 10	1.8	5.3	4.4	53
0:10	1.8	1.3	4.8	51
Self Agglutination	1.4	3.3	4.8	33
0:6, 10	4.0	0.0	1.8	26
0:7	5.0	0.7	1.3	24
0:3, 6, 10,	0.9	0.0	1.9	20
0:4, 6, 9, 10	0.5	2.0	1.5	18
0:9	1.4	5.3	0.5	16
0:4, 9, 10	0.9	2.6	1.1	16
0:3	1.4	0.0	1.3	15
0:3, 4, 7, 9, 10	0.9	5.3	0.4	14
0:1, 4	1.4	0.0	1.1	13
0:10, 5d	0.5	1.3	1.0	12
0:9, 10	0.9	2.6	0.6	12
0:3, 4, 6, 10, 5d	0.0	0.0	1.2	11
0:4, 6	1.4	0.0	0.7	10
0:4, 7, 9	0.9	5.3	0.0	10
Location Total	244	151	938	1315

Generally, the common serotypes were encountered, with varying frequencies from all three location types, shoreline, mid-lake, and beach. The differences between the frequencies of recovery of individual serotypes at each of the three locations may be attributable to the differences in the total number of cultures serotyped from each of the three locations.

4.6.1 DISCUSSION OF TYPING RESULTS

Serotypes 0:1, 0:11, 0:4, 0:6, 0:5d, 0:10, 0:3, and 0:3, 4, 6, 10, 5d (Table 21) were encountered with similar frequency in the ears of swimmers and of *otitis externa* patients (suggesting that the organisms from both sources were closely related). The frequency with which serotype 0:6, 10, serotype 0:4, 5d, self-agglutinating, and untypable isolates were encountered in the ears of swimmers differed from the frequency in the ears of *otitis externa* patients.

The role of water in the transmission of *P. aeruginosa* related diseases to humans, domestic animals, and plants is well documented in the literature (Hoadley 1977). However, confusion abounds over the normal habitat of this organism. One group of scientists favours plants and soil as the natural and permanent reservoir of the organism, whereas the other

group believes the human intestine and the resulting human sewage to be the primary source of the organism (Young 1977). Laboratory experiments have shown that *P. aeruginosa* may be able to grow in the environment in organically enriched surface waters where the water temperatures exceed 30°C. *P. aeruginosa* has seldom been recovered from cold surface waters except following rains or recent contamination by human feces or sewage (Hoadley 1977).

The frequency of recovery for the common serotypes, varied markedly from the beach location to the lake shoreline and mid-lake locations (Table 23). A higher percentage of the beach isolates belonged to serotypes 0:1, 0:11, 0:5d, 0:6, and 0:10 than either the shoreline or mid-lake isolates. Similarly, a higher percentage of the shoreline and mid-lake isolates belonged to serotype 0:4 than the beach isolates. The percentage of untypable cultures from shoreline and mid-lake locations were similar, whereas the percentage of untypable cultures from the beach was much lower. Of the isolates serotyped from the beach locations, 52.2 percent produced single serotypes, whereas 42.1 percent of the shoreline isolates produced single serotypes, and only 21.2 percent of mid-lake isolates produced single serotypes.

These differences in the frequency of individual serotypes and of total single serotypes were significant in that the procedures available to characterize *P. aeruginosa* serologically were developed for medical strains. If the *P. aeruginosa* originated from the swimmers themselves, than the differences in recovery frequency were logical. The *P. aeruginosa* recovered from the beach, having originated from the swimmers, were more closely related to medical isolates than are the *P. aeruginosa* recovered from lake shoreline or mid-lake locations where human recreational activities are less intense. It is not known whether the isolates recovered from lake shoreline and mid-lake locations were of human origin and with time underwent serological changes or whether they were innately different having originated from plants and soil.

The serotyping program showed that the *P. aeruginosa* recovered from both the ears of swimmers and of *otitis externa* patients to be closely related. The *P. aeruginosa* from beach waters and the ears of swimmers were also closely related. These results, therefore, suggested that the *P. aeruginosa* commonly encountered in bathing waters were likely of human origin and that water is a vector by which *P. aeruginosa* can be transferred from one swimmer to another.

Table 24. Comparison of serotyping results between the present study and those of Seyfried (1976) and Fraser (1977).

Serotype	Present Study %	Seyfried (1976) %	Fraser (1977) %
0:6	5.7	40.16	30.82
0:10	3.9	18.03	17.40
0:3	2.1	11.48	11.53
0:1	10.5	6.56	7.65
0:11	8.8	4.10	14.02
Untypable	13.3	1.64	2.78
Multiple:			
Beach	33.4	)	)
Shoreline	36.1	)0	)0.49
Mid-Lake	55.6	)	)
Total Number of isolates	1612	122	1006

The results of the serotyping programs can be compared with the works of Seyfried (1976) and Fraser (1977) who employed the same serotyping scheme (Duncan et al 1976) (Table 24). Of the 122 *P. aeruginosa* isolated from Muskoka lakes (Seyfried 1976) 40.16 percent were serotype 0:6, 18.03 percent were 0:10 and 11.48 percent were 0:3. Only 1.64 percent of these isolates were untypable. In the present study, the frequencies of serotypes 0:6, 0:10, and 0:3 were much lower and the frequencies of the untypable isolates were much higher. Seyfried encountered no multiple serotypes, whereas in this study, 36.1 percent of shoreline cultures and 55.6 percent of mid-lake cultures displayed multiple serotypes. Fraser (1977) examined *P. aeruginosa* in Lake Ontario, sewage effluent, swimming pools, and ears. Serotypes 0:6, 0:1, 0:11, 0:3, and 0:10 were recovered from the environmental sources with the highest frequencies. From the ear isolates, serotypes 0:6, 0:3, 0:1, 0:10 and 0:11 were recovered most often. In the present study of *P. aeruginosa* isolates recovered from outer ears of swimmers, serotypes 0:1, 0:6, 0:10 and 0:3 were encountered most frequently.

Cultures which yielded multiple serotypes accounted for 33.4 percent of beach isolates, 36.1 percent of shoreline isolates, and 55.6 percent of mid-lake isolates in this study while no cultures yielding multiple serotypes were encountered by Seyfried and 0.49 percent of cultures serotyped by Fraser yielded multiple serotypes. Generally where isolates give positive reactions to two or more serotypes, the results are not as reliable for tracing purposes as those from cases where isolates react positively for only one serotype (Duncan et al 1976). A variety of factors can cause the occurrence of multiple serotypes (Homma et al 1972; Pitt and Erdman 1977).

Although Seyfried and Fraser employed the same serotyping scheme in their respective studies of *P. aeruginosa*, the testing anti era were slightly different. Duncan et al (1976), however, conducted a study in which the two sets of antisera were shown to be comparable in performance.

The present study demonstrated the wide distribution of many *P. aeruginosa* serotypes. No serotype of *P. aeruginosa* was observed to be unique to any one geographical location or to an environmental or human source. The results of the serotyping program combined with the results of the ear swabbing program and the water quality assessment programs support the thesis that the major source of *P. aeruginosa* in bathing waters is the swimmers themselves with the water as the vector for transmission from one swimmer to another.

4.7 INFECTION CASE RATE VERSUS *P. AERUGINOSA* LEVELS

On all questionnaires, there was at least one question which required the respondent to give a list of locations at which they swam and three to five spaces were provided for a write-in answer. This question was then coded so that all questionnaires could be categorized by the locations at which the respondent swam. The ear infection case rate for those persons who swam at a particular location can be compared with that for those who did not report swimming at that location and with the general case rate across all questionnaires (Table 25).

Table 25. Case rates of *otitis externa* ear infection in users of the 1979 study lakes and beaches.

Lake/Beach (1979)	Case Rate/100 Users Total Body of Water (Lake and Beach)	Beach only	Lake only
Gull	10.4	11.7	8.6
Head	4.3	3.6	10.0
Pine	11.3	11.9	8.0
Mary	8.0	8.3	8.1
Vernon	7.3	8.0	0.0
12 Mile	9.5	-	8.7
1) Public	-	0.0	-
2) Red Cross	-	10.8	-
Muskoka	6.3	-	-
General Response	7.6		

number of questionnaires summarized = 995.

In 1979, Gull Lake beach, Pine Lake beach and Red Cross beach on 12 Mile Lake gave higher case rates than were seen at the corresponding lakes or the general response. Head Lake beach and Public beach on 12 Mile Lake gave aberrantly low case rates. At all other locations reported on the 1979 questionnaires there were too few responses to give an accurate picture of the case rate.

From the 1978 questionnaire, two bodies of water, Gull Lake and Muskoka Lake, reported a sufficient number of questionnaires to give a case rate. They gave case rates of 14.7 and 9.0 respectively per 100 users as compared to a general response case rate of 10.0 per 100 users. The Gull Lake beach data were not separated from the rest of the Gull Lake data.

From the 1978 and 1979 case rates, Gull Lake beach, Pine Lake beach and 12 Mile Lake Red Cross beach contributed to an increased level of ear infection among the user population. Because the summer was used as the base for time, the risk of contracting an ear infection by using the swimming location was assumed uniform over the entire period. However, the risk was seasonally variable as seen from the dates when users acquired an ear infection. Therefore, the summer case rate will be underestimating the maximum case rates that could be expected at mid-summer and peak-use periods.

The *P. aeruginosa* concentrations which can be associated with a particular risk of contracting the disease or a particular case rate need to be examined from two perspectives: the concentrations actually associated with a given level of disease incidence and the underlying mechanism of acquiring the disease. In the case of *P. aeruginosa*, the disease causing organism is being measured directly, instead of through a secondary indicator such as fecal coliform. Therefore, if the disease causing organism is present, a risk of contracting the disease exists and the concentration of the organism is a measure of the magnitude of that risk. This means that the risk for a particular individual is related directly to the concentration of the organism to which he is exposed and not to some measure of an average state. The extremes of the distribution of concentration and especially the high values are, therefore, important in the assessment of the risk to an individual.

In 1979, the median concentration of *P. aeruginosa* at all locations was 0 bacteria per 100 mL since less than 50% of the samples contained any *P. aeruginosa* (Table 7). Locations could not be distinguished from each other by their average state, even if there was a difference in the disease case rate. The maximum concentration of *Pseudomonas* fluctuated radically with both location and time. The 75 percentile concentration of *P. aeruginosa* provided a realistic and more stable measure of the high concentration found in any time period. The 75 percentile concentration is defined as that concentration below which 75% or three-quarters of the concentrations are observed. The 75 percentile *Pseudomonas* concentrations for most shoreline locations was 2 bacteria per 100 mL or less (Figure 14). However, for beach locations, the 75 percentile concentration regularly exceeded 10 *Pseudomonas* per 100 mL and occasionally went into the range 100 to 1000 *Pseudomonas* per 100 mL (Figure 17). The 75 percentile *P. aeruginosa* concentrations did reflect the differences in disease case rate seen between lake shoreline and beach locations and therefore, the risk of contracting an ear infection.

5. CONCLUSIONS AND IMPACTS

In the introduction, a goal of the Microbiology Component of the Lakeshore Capacity Study was to define and quantify the influences of lakeshore development and the associated recreational activities upon the bacteriological quality of the lake water and the infections among the human users of the water. Other microorganisms are important to the public health of the people in the study area. The importance of maintaining adequate treatment of the water used for drinking, washing and food preparation and of the sewage produced by a development cannot be stressed strongly enough. In the examination of any proposal for development, these areas must be considered if the health of the people is to be safeguarded.

In this study, the research was restricted to one organism, *P. aeruginosa*, and one disease, an ear infection called *otitis externa*. As a result of our study, a number of component parts of a model presented as a flow diagram in Figure 1 have been examined. This model is supported by the general microbiological literature, by the general inclination of microbial ecology and by the findings of our study.

In the Muskoka-Haliburton lakes *P. aeruginosa* was virtually absent except where human activity was great, e.g. at a beach. The regression analyses and the time trend of isolation of *Pseudomonas* suggested that temperature played a major part in the occurrence of *P. aeruginosa*. *Pseudomonas* was more frequently recovered as temperatures in the lake water increased above 20°C into the range 24 to 25°C, the period of time between mid-July and mid-August. The question of nutrients and organic enrichment and their effects on *Pseudomonas* levels was not resolved by this study.

In the current study, up to 3% of the swabs from healthy swimmers' ears taken before swimming and up to 8% of the swabs from healthy swimmers' ears after swimming activity were positive for *P. aeruginosa*. When the swabs submitted by local physicians from diagnosed cases of *otitis externa* were examined, 58% showed presence of *P. aeruginosa*. The swimmer and cottage questionnaires showed that between 8% and 12% of the swimming population experienced an ear infection during the summer months. The control population, which did not swim, were not represented because the survey was carried out mainly at the beach. In the ear swabbing portion of the study, 33 members of the swimming class at Gull Lake beach at one point in time had *Pseudomonas* present in their ears. Of the 22 subsequently completing the questionnaire, 3 (13%) reported that they developed an ear infection. Both the incidence of ear infections and the levels of *Pseudomonas* in the water were highly seasonal. The levels of *Pseudomonas* were very low (0 to 30 per 100 mL) and very highly variable (a few samples with up to 1000 per 100 mL).

In summary, the combination of results reported in the literature and the findings of this study can place values on the levels of occurrence of *P. aeruginosa* in each of the main boxes of the model. About 10% of the normal healthy human population carry *Pseudomonas* in their gastro-intestinal system and excrete it in their feces. In 'northern temperate surface waters' not affected by humans, *P. aeruginosa* levels are extremely low and virtually absent. These levels are affected by water temperature and the amount of human influence. *P. aeruginosa* is found in a low percentage of normal healthy ears, 10 to 14% (Hoadley and Knight 1975), 1% (Singer et al 1952) and 3% (this study). This study suggested that this percentage was increased when measured after swimming. The *otitis externa* ear infection was between 7 and 12% for people who swam. Of the *otitis externa* cases, 58% showed *P. aeruginosa*.

However, this study did attempt to go beyond the simple enumeration of *P. aeruginosa* and to examine some of the interactions.

In the 1978 Gull Lake beach study, the following multiple linear regression equation was developed:

$$\log (PsA + 1) = -0.72 + 0.041\ WTEMP - 0.164 \log (FC + 1) + 0.0048\ TPREV$$

where FC and PsA were the levels of fecal coliform and *P. aeruginosa* per 100 mL, WTEMP was the water temperature in degrees Celsius and TPREV was the total number of users in the previous hour at the swimming area. This relationship was not obtained when the study was repeated at the same location the following year or at different locations. This non-reproducibility was probably due to the extreme variability of the data, erroneous statistical assumptions and the very low level of the *Pseudomonas* in the surface water.

At Gull Lake beach in 1979, the people who swam at the beach developed ear infections at a rate of 12% or 12 infections per 100 users. At this beach, 75 percentile levels of 10 *Pseudomonas* per 100 mL and greater were present on a number of occasions. In the case of cottaged shoreline areas, the people developed ear infections at a rate of 8% or less. The 75 percentile levels of 2 or less *Pseudomonas* per 100 mL were usual. The important levels of *P. aeruginosa* where the effect of increased ear infections can start to be seen are in the range of 2 to 10 *Pseudomonas* per 100 mL when examined as a 75 percentile value.

If a water quality criterion value was wanted, a 75 percentile *P. aeruginosa* concentration of 10 bacteria per 100 mL would be the best current choice, since above that value a noticeable increase in the disease rate was present. Operationally, this

water quality criterion value could be used in the following fashion: If more than one quarter of the samples taken at a particular location contain more than 10 *P. aeruginosa* per 100 mL, then the water quality criterion has been exceeded and there is a significant risk to swimmers of getting an ear infection. The action to be taken at this occurrence would be to limit the number of swimmers since the swimmers are the source of the bacteria. However, since the results of the sample analyses are not available immediately, this action could only be applied when the location in question historically has the elevated levels of *Pseudomonas*. From this study, this action would rarely be required for most lakeshore cottage development but may be required for heavily used bathing beaches.

5.2 IMPACT OF THE MODEL AND THE STUDY RESULTS

The results of the Lakeshore Capacity Microbiology Component study and the literature suggest that the model which was proposed can be validated. However, the current results do not allow the model to be stated as a fully quantified mathematical model, but only as a qualitative model with some sections having quantitative data. The results and the model do provide a basis for suggesting a *P. aeruginosa* water quality criteria for use in Ontario and design criteria for swimming areas in order to minimize the risks of *otitis externa* ear infections.

When the 75 percentile concentration of *P. aeruginosa* exceeded 10 bacteria per 100 mL, there was a noticeable increase in the incidence of ear infections among the swimmers at that location. This level of bacteria contamination can, therefore, be set as a water quality criterion. When the *Pseudomonas* concentrations in a swimming area regularly exceed this water quality criterion, the users of the area have a greater risk of contracting an ear infection and the use of the swimming area should be restricted until the cause of the situation has been clarified and/or rectified.

When designing a swimming area in association with a cottage development, the design should also take into consideration the risk of bacterial contamination. The swimming area should be located away from and upstream of possible sources of sewage and sewage impacted soil runoff. It should be located away from shallow, organically rich, marshy areas which may be warmed by the sun or by a thermal input and should be designed to have a good flushing or dilution with water from outside the impacted area. Human users should be dispersed over as wide an area as possible. These factors in the design are intended to reduce the intensity of swimmer use or to reduce the *P. aeruginosa* levels and thereby reduce the likelihood of *otitis externa* ear infections.

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7. APPENDIX A

This appendix contains a copy of the various questionnaires, forms and descriptive letters used by the Microbiology Component in the years 1978 and 1979.

1978

1) Letter and questionnaire for swimmers and beach users

1979

1) Letter, instruction sheet and card questionnaire for beach users
2) Physician questionnaire and letter
3) Patient questionnaire and letter

Ontario

Ministry of the Environment

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May 5, 1978

Dear Sir or Madame,

Each year numerous swimmers encounter ear infections associated with the bacteria Pseudomonas aeruginosa. This organism has been associated with ear infections (otitis externa) of users of swimming pools and because it is often encountered in lake water, it may also be involved as a causative agent of ear infections of swimmers at recreational lakes. For these reasons the Ontario Ministry of the Environment is conducting an extensive study of bacterial ear infections associated with swimmers at recreational lakes in the Muskoka area.

In order to gather information concerning the swimming habits and incidence of disease of users of recreational waters, we request your cooperation in providing us with this information. In the month of August, with your permission, we will send to you a questionnaire concerning your swimming habits and experience with ear infection during the summer months. Additional copies of this questionnaire will be provided at that time for members of your family who also may wish to participate in the study. Along with these questionnaires you will receive stamped, self-addressed envelopes to provide a convenient means for you and your family members to return the completed questionnaires. Answers to these questions from both swimmers and non-swimmers are essential to the success of the study and will greatly assist the Ministry of the Environment in its efforts to determine the corrective measures required to eliminate potential health hazards in lake waters used for recreational purposes. Information gathered from participants in this study will be kept strictly confidential.

A sample questionnaire has been provided with this letter to convey examples of the type of information that we will request from you near the end of the summer. We hope that this sample questionnaire will assist you in maintaining a record of your general swimming habits during the summer months.

We believe that this research will demonstrate the significance of Pseudomonas aeruginosa as an indicator of health risks to users of recreational lakes and that the findings will be of interest to all swimmers. For your participation in this important study we are sincerely grateful.

Sincerely yours,

Allan Burger

A. Burger, Supervisor,
Microbiology Section.

Karl Lautenschlager

K. Lautenschlager,
Scientist,
Lakeshore Capacity Study.

MINISTRY OF THE ENVIRONMENT
Microbiology Laboratory #8
P.O. Box #8
Dorset, Ontario
P0A 1E0

SWIMMER'S AND NON-SWIMMER'S QUESTIONNAIRE

Please answer all questions that pertain to your personal situation by supplying the appropriate information or by circling the most appropriate typed answer. After completing the questionnaire, please enclose it in the attached envelope and forward it by mail.

1. What is your Name? _____

2. What is your sex? Male _____ or _____ Female.

3. What is your age? _____ years.

4. Are you a swimmer or a non-swimmer? _____ Swimmer or _____ Non-Swimmer.

5. If you are a non-swimmer, do you usually wade or otherwise splash about in waters used by swimmers? _____ Yes or _____ No.

6. At what bodies of water did you swim or wade during this summer? Please indicate the names of the water bodies and also the type of swimming facilities at each site (e.g. private pool, public beach, river, lake shoreline, cottage, etc.).

Name of Water Body	Type of Swimming Facilities
A _____	_____ A
B _____	_____ B
C _____	_____ C
D _____	_____ D
E _____	_____ E

7. At which body or bodies of water did you swim or wade most frequently? _____

_____

8. How often did you usually swim during the summer months? _____ Times per day; _____ Times per week.

9. When you did swim or wade for how long did you usually remain in the water? _____ hour(s) per swim; _____ hour(s) per day.

10. On the average, how many hours per week did you spend swimming during the month of May, June, July and August? .....

In May _____ ; In June _____; In July _____; In August _____.

11. During each of these months, on days when you swam, at what time(s) of day or night did you usually swim? _____ (Please indicate AM or PM)

In May _____; In June _____;

In July _____; In August _____.

12. On what day(s) of the week during each month did you usually swim?

Month	Days of the Week						
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
May	1	2	3	4	5	6	7
June	1	2	3	4	5	6	7
July	1	2	3	4	5	6	7
August	1	2	3	4	5	6	7

13. At the sites at which you most often swam this summer, approximately how many other swimmers were usually present in the water at the times when you were swimming?

Swimming Sites	Approximate Number of Other Swimmers Present				
	None;	a Few;	Several;	Many	Very Many
_____	1	2	3	4	5
_____	1	2	3	4	5
_____	1	2	3	4	5

14. Do you consider the sites at which you swam to be of good water quality? _____ Yes or _____ No.

	Yes	No
15. Do you dive?	Y	N
16. Do you swim under water?	Y	N
17. Do you wear a bathing cap?	Y	N
18. Do you wet your head while swimming?	Y	N
19. Do you wear ear plugs or other forms of ear protection while swimming?	Y	N
20. Have you ever experienced an ear infection?	Y	N
21. Do you often experience ear infection?	Y	N
22. Did you experience an ear infection this summer?	Y	N

** The following questions should be answered only by swimmers who have experienced ear infection.

	Yes	No
23. If you experienced an ear infection this summer did you associate the infection with your swimming activities?	Y	N
24. If you experienced an ear infection this summer did you seek medical treatment?	Y	N
25. If you experienced previous ear infections were they treated by a physician?	Y	N
26. Have you ever been hospitalized for an ear infection?	Y	N
27. If you experienced an ear infection this summer were you already receiving medication for another ailment when the symptoms of ear infection appeared?	Y	N

28. If you experienced previous ear infections on what date(s) or at what time(s) of year did they occur? .....

_____

29. If you experienced an ear infection this summer on what date (approximately) did the symptoms first occur? ..... _____

** The following questions should be answered only by swimmers who experienced an ear infection this summer.

30. In the two-week period just before the onset of the symptoms of ear infection at what water bodies had you been swimming? ..... _____

Site 1: _____ Site 2: _____ Site 3: _____

31. During the two-week period just prior to the onset of symptoms how many times had you been swimming and for how long did you stay in the water usually? ..... _____ Times swimming; _____ hour(s) in the water on each swimming occasion (average).

32. For how long did you experience ear infection symptoms before you obtained medical treatment: ..... _____ days; _____ weeks.

33. In what community did you obtain medical treatment? ..... _____

34. Any comments concerning the waters in which you swam: _____

_____

_____

We express our sincere gratidude for your cooperation in this study.

Ontario

Ministry
of the
Environment

135 St. Clair Avenue West
Suite 100
Toronto, Ontario
M4V 1P5

Microbiology Laboratory #8
P.O. Box 58
Dorset, Ontario P0A 1E0

Tel. 705-766-2712

June 20, 1979

Dear Patient or Guardian;

The Ontario Ministry of the Environment is conducting a investigation into the incidence and causes of ear infections associated with the bacterium, Pseudomonas aeruginosa. The Ministry is particularly interested in obtaining information from individuals who have suffered from ear infections that may be related to the presence of this bacterium in recreationally-used lake water. To obtain the necessary information, we would very much appreciate your cooperation by completing the attached questionaire.

The Patient's Survey of Ear Infection (Otitis Externa) provides us with information concerning your swimming activities and the history of your ear infection. All answers on the questionaire are very important to the success of the study. Your doctor will also be providing us with some of detail of the symptoms and the prescribed treatment but we need you to provide some details about your current swimming habits. The information that you provide will be kept in the strictest confidence and only code numbers, never the names, will be used in reports concerning the findings of the investigation.

A stamped, self-addressed envelope has been provided with the questionaire for your convenience. Your cooperation in our study is sincerely appreciated.

Sincerely yours,

Allan Burger

A. Burger, Supervisor
Microbiology Section

Karl Lautenschlager

K.P. Lautenschlager, Scientist
Lakeshore Capacity Study

Ontario

Ministry of the Environment

135 St. Clair Avenue West
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Microbiology Laboratory #8
P.O. Box 58
Dorset, Ontario P0A 1E0

CODE:_____/_____.

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Physician's Survey of Otitis Externa

1. Date of treatment ..... _____/_____/ 1979
   Day Month

2. Date of onset of symptoms ..... _____/_____/ 1979
   Day Month

3. Describe the symptoms at the time of diagnosis
   (circle the appropriate answer)

Pain:-	None	Slight	Moderate	Severe
Swelling:-	None	Slight	Moderate	Severe
Discharge:-	None	Slight	Moderate	Severe

4. Ear(s) infected:- Left Right Both

5. Does the patient have a history of ear pathology? Yes No

6. Is there a concomitant infection? Yes No

7. Was there any recent prior antibiotic treatment? Yes No

8. Was hospitalization required for this case? Yes No

9. Comments:

Ontario Ministry of the Environment

NAME_____
Surname Given Names

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Survey_____ 1. Age (years)_____

Date_____, 1979 2. Sex: M F

Circle the appropriate answer to questions:

3. TOURIST LOCAL COTTAGER RESIDENT

4. Swim: NEVER OCCASIONALLY FREQUENTLY VERY

5. Head: Y N	9. Hosp: Y N	13. Assoc: Y N
6. Class: Y N	10. Self: Y N	14. Sites: Y N
7. Ever: Y N	11. This: Y N	15. Participate: Y N
8. Treat: Y N	12. Treat: Y N	

16. First lake swimming _____, 1979

17. Name sites: A_____ B_____

C_____ D_____ E_____

22. Date previous onset: _____

23. Date this summer onset:_____, 1979

24. Community treated: _____

25. Doctor: _____

SUMMER MAILING ADDRESS PERMANENT ADDRESS

_____ _____

_____ _____

TEL. NO. TEL. NO.

Ontario
Ministry
of the
Environment

P.O. Box 58
Dorset, Ontario
P0A 1E0

The Ontario Ministry of the Environment as part of its Lakeshore Capacity Study is investigating the relationship, if any exists, between water quality and an outer ear infection (otitis externa), commonly known as "swimmer's ear". As part of our investigation we are asking questions of individuals at a number of locations in the Muskoka-Haliburton area. Would you take a few minutes to answer our questions? All information obtained will be strictly confidential and will only be used for the purpose of this study.

(Answers to all questions are to be recorded on the answer card)

I Name -surname, given names

1. Age -in years

2. Sex -male (M) or female (F)

3. Which of the best describes you:

TOURIST	-you are visiting in the area
LOCAL COTTAGER	-you reside within 30 miles of this location for only part of the year
RESIDENT	-you reside within 30 miles of this location year round

4. Which of the following best describes the frequency of your swimming activities:

NEVER	-you are a non-swimmer and do not go swimming
OCCASIONALLY	-you swim up to once, maybe twice, a week, and usually for less than one hour
FREQUENTLY	-you regularly swim between 1 and 4 times per week
VERY	-you regularly swim 4 or more times per week

5. Does your head, especially the area around your ears, get wet while you are swimming?

6. Are you enrolled in a swimming class at this location?

7. Have you ever had an outer ear infection (otitis externa)?

8. Have you ever been treated by a doctor or an emergency ward for an outer ear infection (otitis externa)?

9. Have you ever been hospitalized for an outer ear infection (otitis externa)?

10. Have you ever treated yourself for otitis externa without consulting a medical person using medication from a previous infection or from a drugstore shelf?

11. Have you had an outer ear infection (otitis externa) this summer?

12. Were you treated by a doctor or an emergency ward for otitis externa this summer?

13. Did you associate your ear infection with your swimming activity?

14. Do you regularly swim at more than one beach over the summer months?

15. Would you agree to participate further in this study by answering an additional questionaire that would be mailed to your home later this summer?

16. When (date) was your first swim in lakewater this summer?

17. Where do you regularly swim during the summer? Name the locations including pools. (Note: five spaces have been provided for your answers but all five do not have to be used)

22. When you previously had otitis externa what was the approximate date of the infection's onset include the year?

23. This summer what was the date of the infection's onset?

24. In what community (eg. town, city) did you obtain medical treatment for otitis externa this summer?

25. What was the doctor's name?

II What is your summer mailing address and telephone number?

III What is your permanent address and telephone number?

Thank you for answering our questions. If you have any questions please feel free to contact us.

Ontario

Ministry of the Environment

135 St. Clair Avenue West
Suite 100
Toronto Ontario
M4V 1P5

Microbiology Laboratory #8
P.O. Box 58
Dorset, Ontario P0A 1E0

June 13, 1979

Dear

Each year many swimmers encounter the ear infection, otitis externa, after bathing in recreational waters. Pseudomonas aeruginosa, the bacterium associated with most of these ear infections is frequently detected in lake water used by humans. The Ontario Ministry of the Environment has been studying the relationship which exits between the quality of lake waters and the ear infections of bathers using the Muskoka-Haliburton region as a test area.

In order to determine the incidence of swimming-related otitis externa in recreational areas and to gather information regarding individual cases of this infection, the assistance of physicians in Bracebridge, Gravenhurst, Haliburton, Huntsville and Minden is being requested.

In the lecture slide presentations given to many of the local physicians this spring, some of our preliminary epidemiology findings were reported. The relationships among bather activity, water quality, and the incidence of otitis externa are likely to be established with additional data collection and analysis. However, the success of the study in establishing these relationships will depend on the accuracy of the estimates of the incidence of otitis externa among swimmers in the study area. Some of the information required can only be obtained from the members of the medical profession in the area. We are therefore requesting your participation in the study by providing us with medical information about the otitis externa patients treated this summer and by encouraging each patient to complete a questionaire. Please note that this year we are NOT requesting that ear swabs be taken for our study.

For each otitis externa patient treated, complete the brief Physician's Survey of Otitis Externa form which will serve to confirm the ear infection as a case of otitis externa and will provide us with important information about the patient's symptoms and history of ear ailments. The Patient's Survey of Ear Infection form is to be given to each otitis externa patient and is designed to gather information concerning the patient's swimming activities and the history of this and previous ear infections. This form can be completed and returned by the patient in the self-addressed stamped envelope provided. Both questionaires bear a specific code to assist us in compiling the data as it is returned.

These questionaires will be supplied to your office and to the emergency ward treatment areas of the hospitals in Bracebridge and Huntsville so that you will have ready access to them. The completed physician's questionaires will be picked by our staff on a regular basis until the end of the study in late September.

Your cooperation in this research will be greatly appreciated. If you have any questions concerning this year's study or if you wish to obtain summaries of our earlier study findings please contact us in Toronto (1-416-248-3008) or in Dorset (766-2712). We look forward to working with you over the summer months.

Sincerely yours,

Allan Burger, Supervisor,
Microbiology Section

Karl Lautenschlager, Scientist,
Lakeshore Capacity Study

Ontario

Ministry of the Environment

135 St. Clair Avenue West
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Code: _____/_____

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PATIENT'S SURVEY OF EAR INFECTION (OTITIS EXTERNA)

1. Name: _____

2. Age: _____(years)

3. Sex: MALE FEMALE

4. Summer Mailing Address / Permanent Mailing Address

_____ _____

_____ _____

_____ _____

5. Telephone Number / Telephone Number

_____ _____

6. Date of treatment for otitis externa _____/_____,1979

7. Date of the start of the symptoms _____/_____,1979

8. Are you a SWIMMER NON-SWIMMER (circle answer)

9. In the 2 weeks prior to the onset of symptoms of otitis externa where did you swim?

	Name of Body of Water	Description (eg. cottage, pool, beach)
A	_____	_____
B	_____	_____
C	_____	_____

10. How many other bathers were present in the water when you were swimming at the above locations? (circle the most appropriate answer)

A.....	NONE	1-20	20-200	MORE THAN 200
B.....	NONE	1-20	20-200	MORE THAN 200
C.....	NONE	1-20	20-200	MORE THAN 200

11. On what days of the week do you usually swim? (circle appropriate answers)

MONDAY TUESDAY WEDNESDAY THURSDAY FRIDAY SATURDAY SUNDAY

12. Do you dive?..... YES NO

13. Do you swim under water?..... YES NO

14. Do you wear a bathing cap?..... YES NO

15. Does your head get wet while you are swimming?..... YES NO

16. Do you wear ear plugs or other ear protection?..... YES NO

17. Do you associate the ear infection with swimming?..... YES NO

18. Have you previously had an ear infection?..... YES NO

19. Have you ever been hospitalized for an ear infection?.. YES NO

20. Have you ever treated yourself for otitis externa with medication prescribed for a previous ear infection?..... YES NO

21. Have you ever treated yourself for otitis externa without obtaining medical advice?..... YES NO

22. Have you ever suffered the loss of your recreational enjoyment because of an ear infection?..... YES NO

23. Do you use untreated lake or river water for washing or bathing at your home or cottage?..... YES NO

24. If you had a previous ear infection when did it occur, - month, time of year?

_____

25. Please use the remaining space for any comments:

_____

_____

_____

_____

_____

_____

_____

Your participation in this research is gratefully acknowledged.

Ontario

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Dorset, Ontario P0A 1E0

Tel. 705-766-2712

June 20, 1979

Dear Sir or Madame,

The Ontario Ministry of the Environment is conducting an investigation into the causes and incidence of ear infections associated with the bacterium, Pseudomonas aeruginosa. Previous studies at swimming pools have shown this bacterium to be associated with ear infections known as otitis externa or "swimmer's ear". Because this bacterium may be found in lake waters the Ministry is particularly interested in obtaining from the local residents, cottagers and swimmers concerning their swimming activities and their experiences with ear infections during the summer months.

In the previous two years the microbiologists from the Dorset field laboratory have conducted surveys at several lakes and beaches in Muskoka-Haliburton. From these surveys much new information has been obtained and our understanding of the factors involved in the transmission of bacterial infections through lake water has been enhanced. This year several sites in Muskoka-Haliburton will be examined in a effort to bring the study to a successful conclusion and to firmly establish the relationship between recreational activity/development and the incidence of ear infections.

While we will getting much information from the analysis of water and sediment samples collected at each study site, the information which is essential to the study can only be obtained from the people who use the lake water for swimming and other recreational activites. For this reason we request that you participate in the study by completing the attached questionaire. For your convenience the completed questionaire may be returned directly to the technician from whom it was obtained or, if necessary, a postage-paid mailing envelope will be provided. All answers to this questionaire are very important to the success of this study. It is hoped that, with your participation in the study, practical solutions to this public health problem in recreational water can be formulated.

The information gathered in the questionaires and interviews will be kept in the strictest confidence and only code numbers, never names, will be used in reports from the study. If you you have any questions concerning the study please contact us. Your cooperation in this important research is sincerely appreciated.

Sincerely yours,

Allan Burger

A. Burger, Supervisor,
Microbiology Section

Karl Lautenschlager

K.P. Lautenschlager, Scientist,
Lakeshore Capacity Study